Riparian Forest Buffer Prioritization Framework User Guide

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Introduction

Riparian forest buffers (RFBs) are defined as an area of trees, usually accompanied by shrubs and other vegetation that is adjacent to a body of water, which is managed to maintain the integrity of stream channels and shorelines, to reduce the impact of upland sources of pollution by trapping, filtering, and converting sediment, nutrients, and other chemicals, and to supply food, water, cover and thermal protection to fish and other wildlife (Simpson & Weammert). Riparian buffers have been a widely accepted practice to for water quality improvement for the last 3 decades. Scientific research has proven the ability of riparian buffers to reduce and stop the entry of pollutants into surface waters and groundwater. Field studies have shown that RFBs can be up to 90% effective at removal of nitrogen, phosphorus and sediment from runoff before entering the surface waters. (Lee et al, Haycock & Pinay, Jacobs & Gilliam, Peterjohn & Correll). RFBs have also been found to trap up to 100% of herbicides and pesticides found in runoff (Arora et al, Boyd et al, Lowrance et al).

RFB's are by nature a multiple purpose practice and not only improve water quality but enhance terrestrial and aquatic wildlife habitat, mitigate flooding and recharge groundwater, just to name a few. Riparian Forest Buffers have a wider range of ecosystem benefits the greater the width of the buffer (Figure 1).

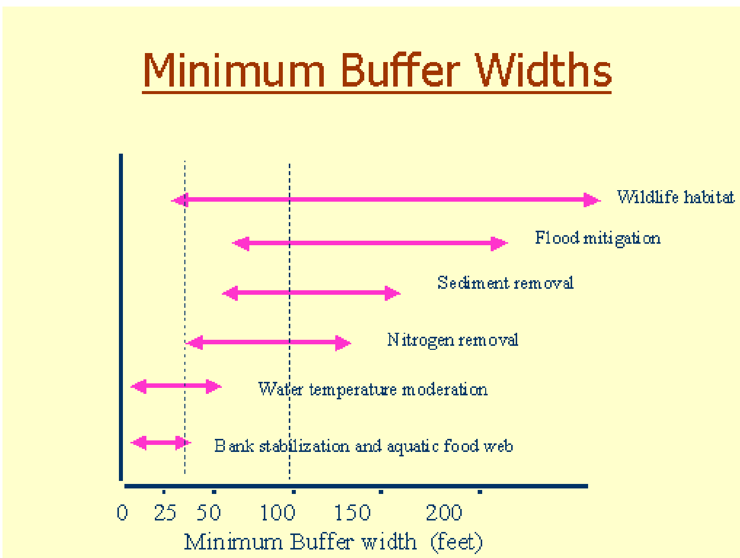


Figure 1: Range of riparian buffer widths to meet various buffer goals. Dashed vertical lines indicate widths that encompass all goals listed. (http://www.riparianbuffers.umd.edu/slideshow/sld022.htm)

1. The Purpose of this Tool

This tool is meant to be used to prioritize areas that most need riparian forest buffers and have the highest nonpoint source pollution (NPS), or runoff, potential. It is NOT meant to be a tool to prioritize areas other than areas most needing riparian forest buffers, nor does it consider in-stream sources of pollution (e.g. phosphorus cycling or stream bank erosion).

2. Tool Users

This tool was developed specifically for individuals or groups that are developing a watershed management plan. Realizing the demands and constraints of many watershed coordinators, typically the person who is responsible for most of the planning, this tool was made to be quick and simple to use, and yet still produce very valuable information.

3. When to Use This Tool

This tool is intended to be a first round assessment or snapshot of *riparian conditions* in a watershed. This is a method by which the large amount of spatial data available can be assimilated into meaningful information. This analysis is not meant to replace ground surveys, but is meant to supplement them, and perhaps be a guide of areas to visit first. This tool has two scales at which it can be used, subwatershed and stream reach.

4. How to Use Tool

This tool allows for riparian buffer placement prioritization on two scales, subwatershed and stream reach. There are 4 indicators for subwatershed scale and 2 for stream reach scale. The data from these indicators or variables is calculated then scored based upon the placement of the data within the complete dataset. The scores from each indicator are then added together or summed to give the final score for the subwatershed and stream reach. Below are the indicators for both scales.

Subwatershed Indicators or Variables

- Percent Riparian Lands
- Percent Nonpoint Source Pollution (NPS) Contributing Land use/ Land Cover (LULC)
- Percent NPS Contributing LULC in Riparian Lands
- Average Annual Estimated Erosion (calculated using Revised Universal Soil Loss Equation) RUSLE

Stream Reach Indicators

- Percent NPS Contributing in Stream reach
- Average Annual Estimated Erosion

4.1 Software Requirements

ESRI's ArcGIS with Spatial Analyst Extension and Excel 2000 or newer is needed to run this model.

4.2 Data needs and preparation

Table 1. Data requirements and information.

Data Category	Data Name	Origin	Year	Resolution/Scale
LULC	National Land Cover Dataset (NLCD)	USGS	2001	30 meter
Soils	STATSGO, SSURGO	NRCS	1994	1:250,000
Elevation Model	Digital Elevation Model (DEM)	USGS	2001	30 meter
Hydrologic Lines	National Hydrologic Dataset (NHD)	USGS	2000	30 meter
Watershed Boundaries	Hydrologic Unit Code (HUC) 10 *	USGS & NRCS	2004	1:24,000
Watershed Boundaries	Hydrologic Unit Code (HUC) 12 *	USGS & NRCS	2004	1:24,000

The above data can be obtained from the following websites.
NLCD http://129.79.145.7/arcims/statewide_mxd/dload_page/environment.html
Soils STATSGO http://129.79.145.7/arcims/statewide_mxd/dload_page/environment.html
Soils SSURGO http://soildatamart.nrcs.usda.gov
DEM http://seamless.usgs.gov/website/seamless/viewer.htm
NHD http://129.79.145.7/arcims/statewide_mxd/dload_page/hydrology.html
Watershed Boundaries http://129.79.145.7/arcims/statewide_mxd/dload_page/hydrology.html

The 10 and 12* digit watersheds were used to clip or extract the DEM, LULC, soil and stream layers. This assured that analysis was only being conducted on the areas of interest.

This data needs to be clipped or extracted to your area of interest, the watershed, or subwatershed you are working in (Figures 2-4). Clipping the data allows faster data processing and makes for a cleaner look. Figure 2 shows how to clip a shape file to a watershed or area of interest. Go to the Analysis toolbox and select “Extract” and then “Clip”. Enter the shape file to be clipped down in the first box labeled “input features” and place the watershed in the “clip features” box. The third box is where this new shape file will be saved so make sure to designate where it is to be saved or it will end up in a temporary file. Keep the units in meters.

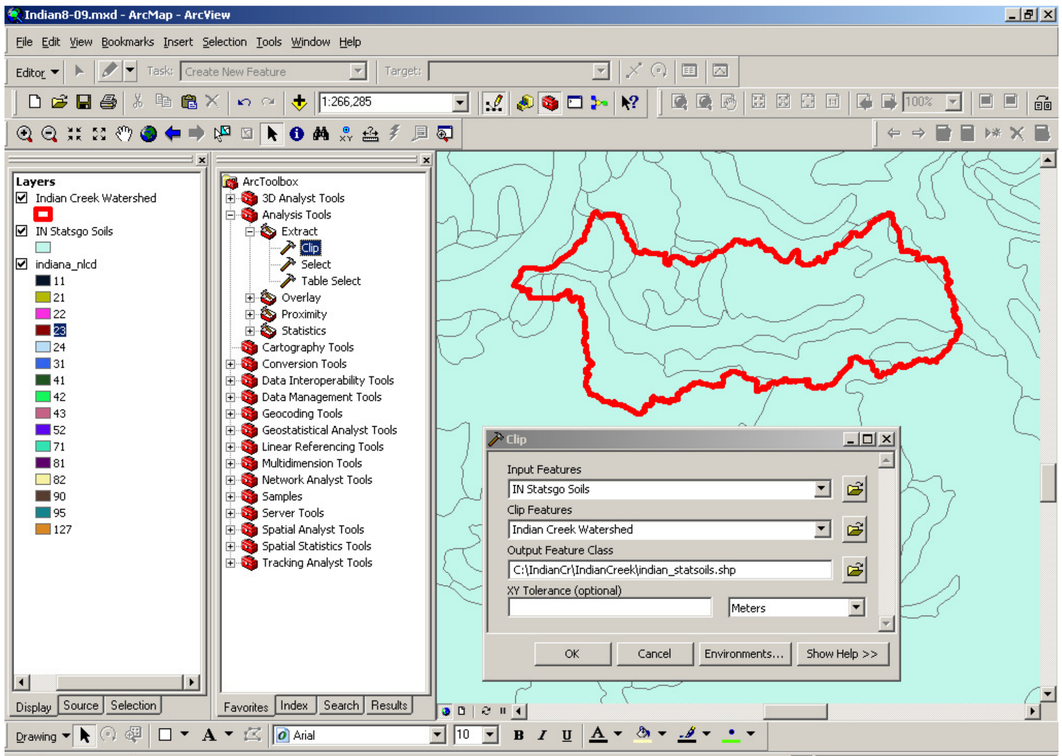


Figure 2. Clipping a shape file.

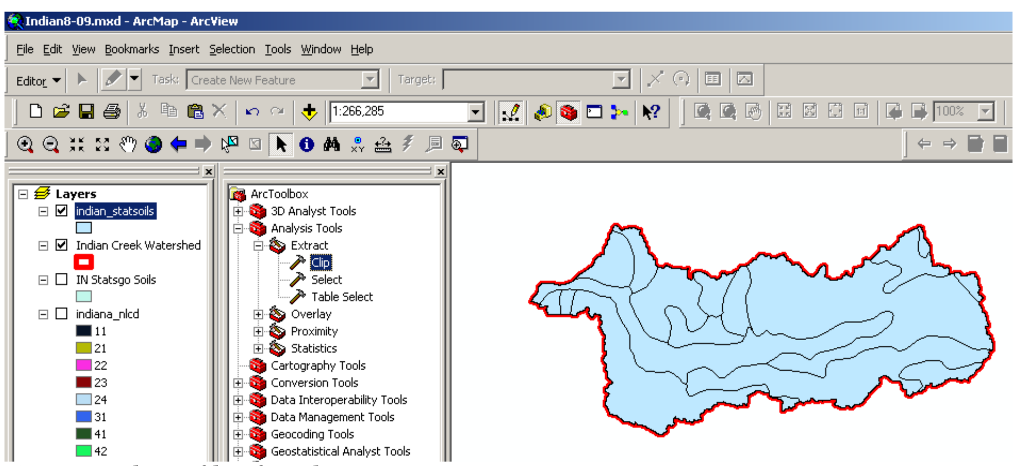


Figure 3. Shape file after clipping.

Clipping raster or grid data is done differently. Figure 4 shows the method for clipping or extracting a raster area. First go to the "Spatial Analyst" toolbox and click on "Extraction" then "Extract by mask". The mask is the area that you want to clip the raster data down to, in this case, the watershed or subwatershed. In the first box select the raster that you wish to extract, in the second box select the mask or watershed. The third box is the file directory that this output data will be saved to, so make sure to select where you want this data to be placed.

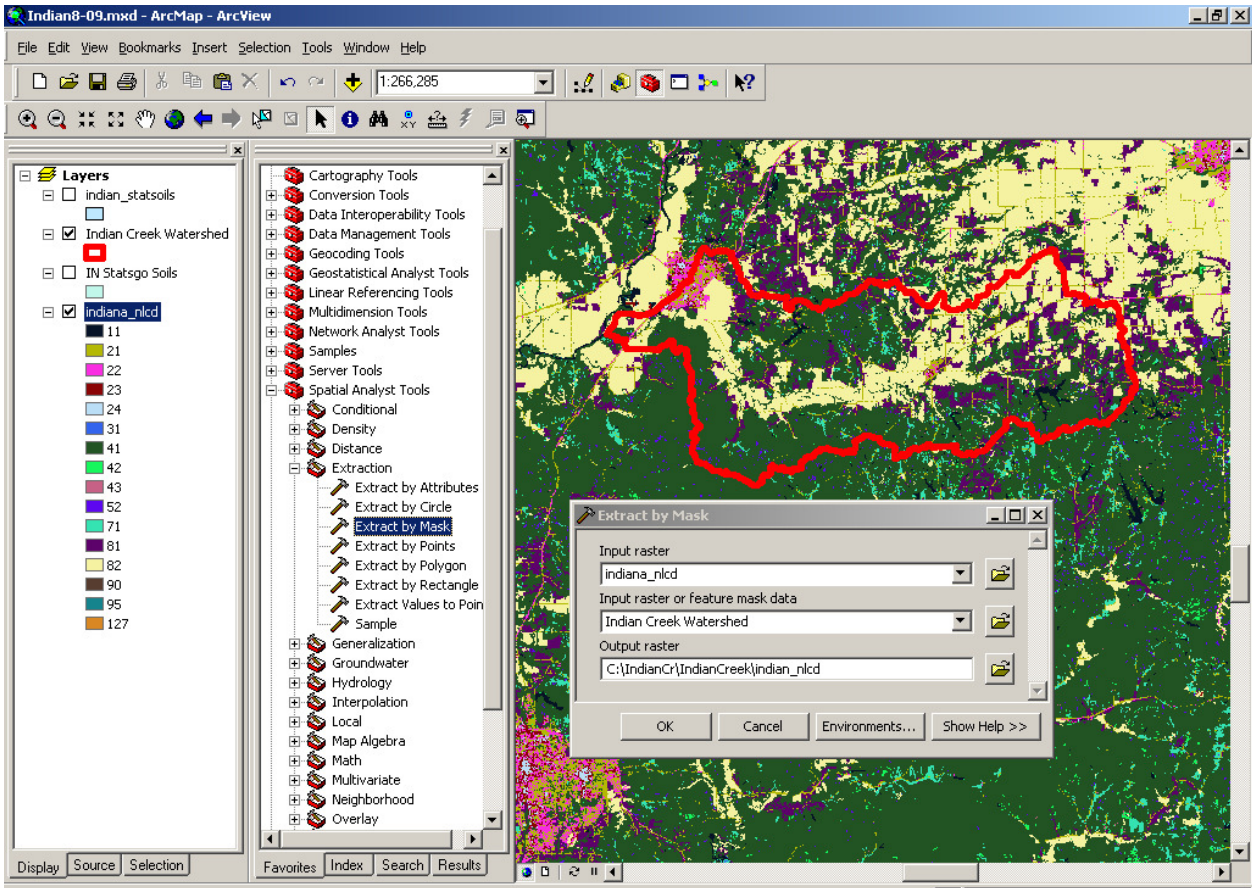


Figure 4. Extracting raster or "grid" data.

4.3 Analysis

This analysis can be performed at two scales, subwatershed and stream reach. These can be used together or separately depending upon the needs of the watershed manager. The subwatershed prioritization is based upon four variables or indicators. These indicators are: percentage of riparian lands within the subwatershed, percentage of NPS contributing land uses within the subwatershed, percentage of NPS contributing land uses within the riparian zones and the RUSLE erosion estimate for the subwatershed. There are two indicators for the stream reach scale, RUSLE erosion estimate for the stream reach, percent of NPS contributing land use within the stream reach.

4.3.1 Subwatershed Prioritization

A) Percent Riparian Lands

*(Total area of buffers around streams, lakes and wetlands in subwatershed / Total area of subwatershed) * 100= % Riparian Lands*

To determine the proportion of riparian lands within the subwatersheds, place a 30 meter* buffer around the streams in each watershed (Figure 5). First to buffer the streams, go to the Analysis Tools, then to Proximity, then select the buffer function. In the first dialog box enter the layer to be buffered, in this case, the stream layer. In the next box direct where the resulting buffer layer is to go and what the name will be. The next box is the linear unit, in this case it is 30 meters. The only other box that needs to be modified is the "dissolve type", change the default from "none" to "ALL". The resulting buffer layer is then used as a mask to extract the land use layer, see Figure 3, and extraction explanation above.

* A 30 meter buffer was used for the needs of certain watersheds. However a larger width can be used if desired. A buffer width of less than 30 meters in not recommended as the resolution of the majority of the available data is 30 meters.

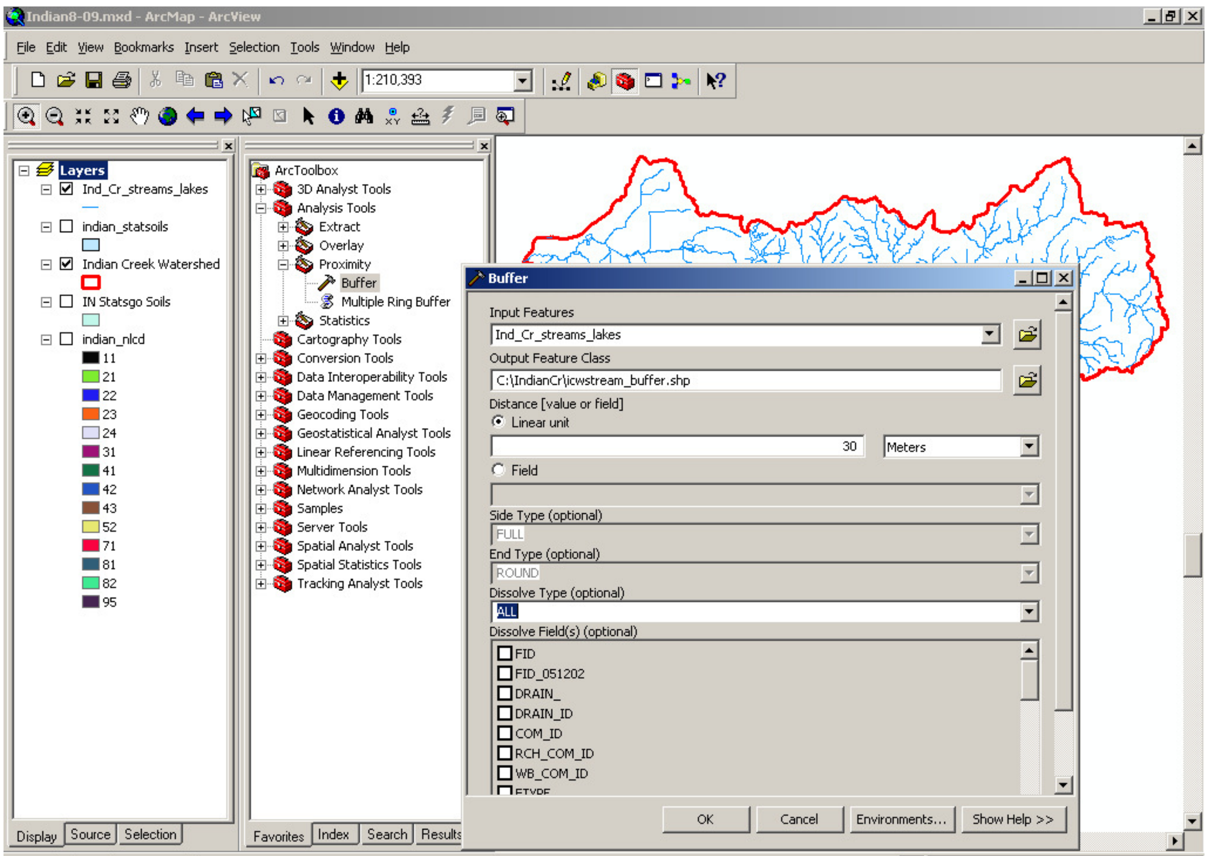


Figure 5. Creating buffers around streams.

After this is done export the attribute table of the buffered stream layer as a dbf, then save as an excel file. To do this, right click on the layer, a drop down menu will appear. Click attribute table, when it appears there will be an "option" button in the lower right corner of the table, click this. The menu that appears will have an "export" option near the bottom of the list, click this (Figure 6). The table will export as a "dbf" file type, open this with excel and then save as an excel file so that you can perform calculations.

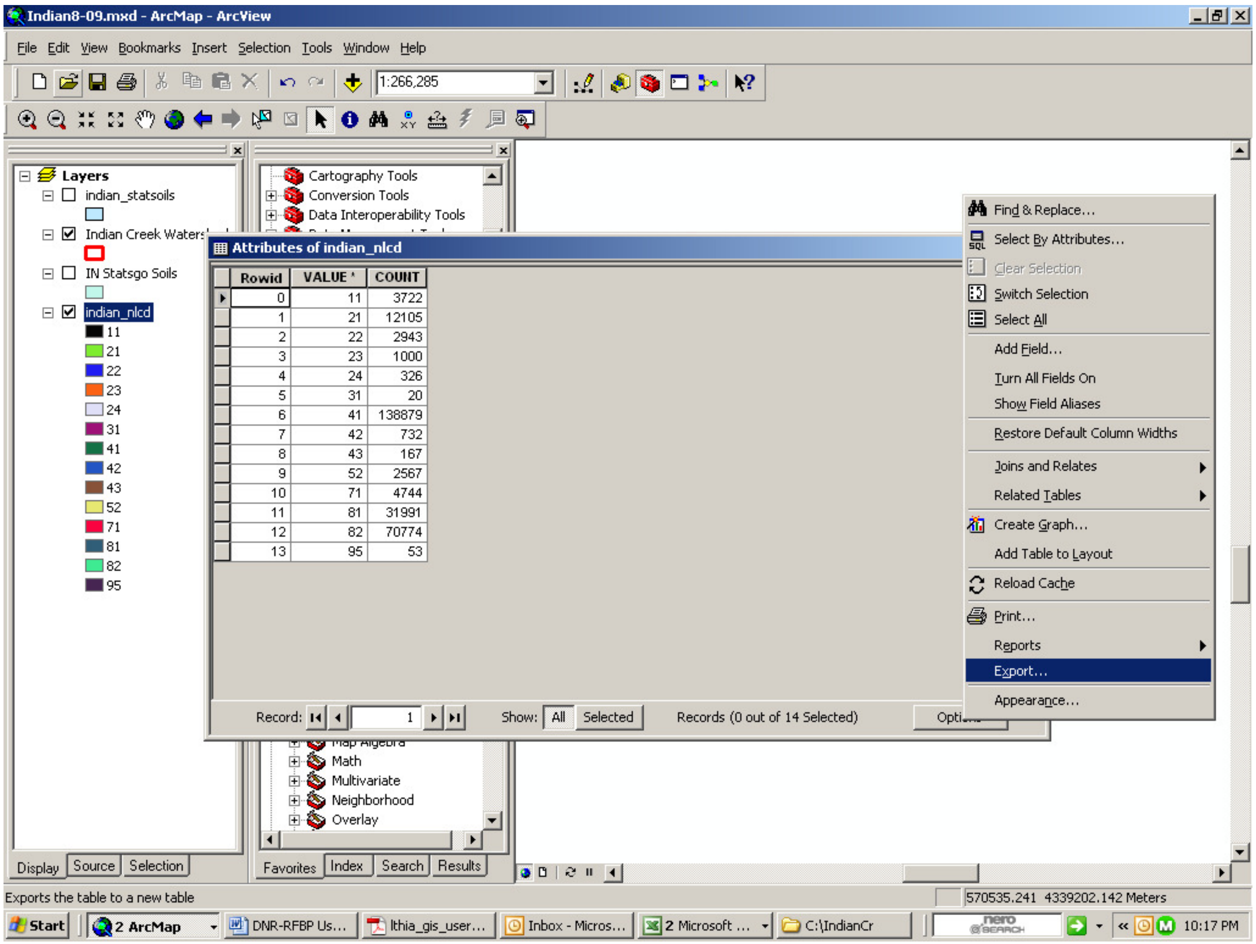
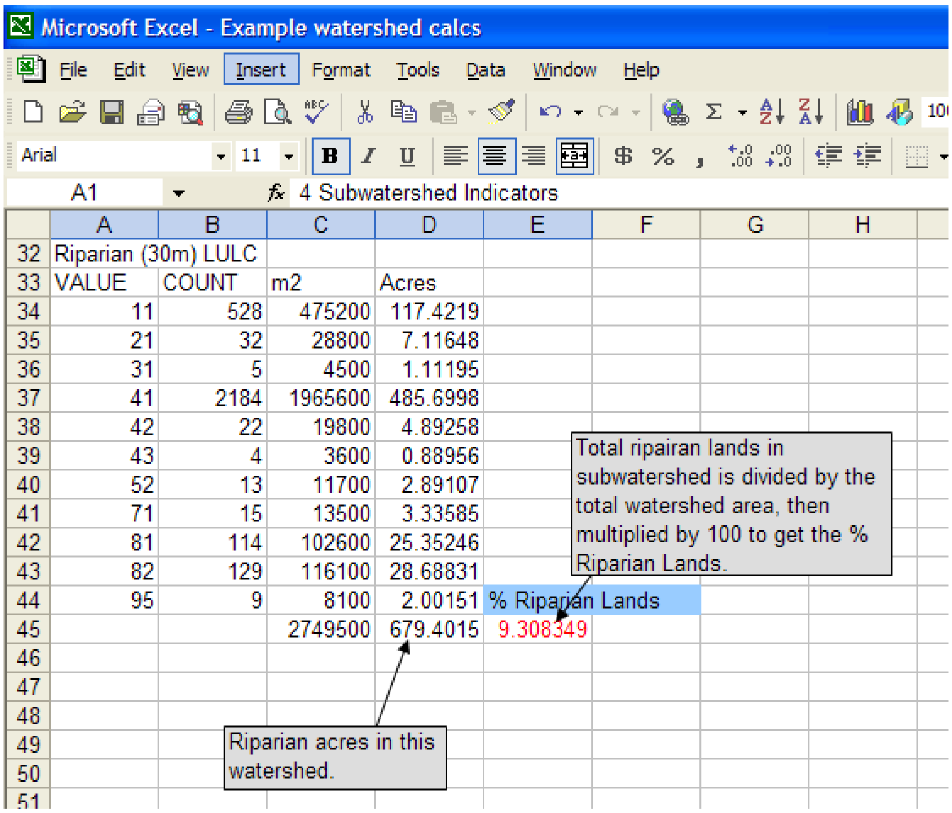


Figure 6. Exporting attribute tables.

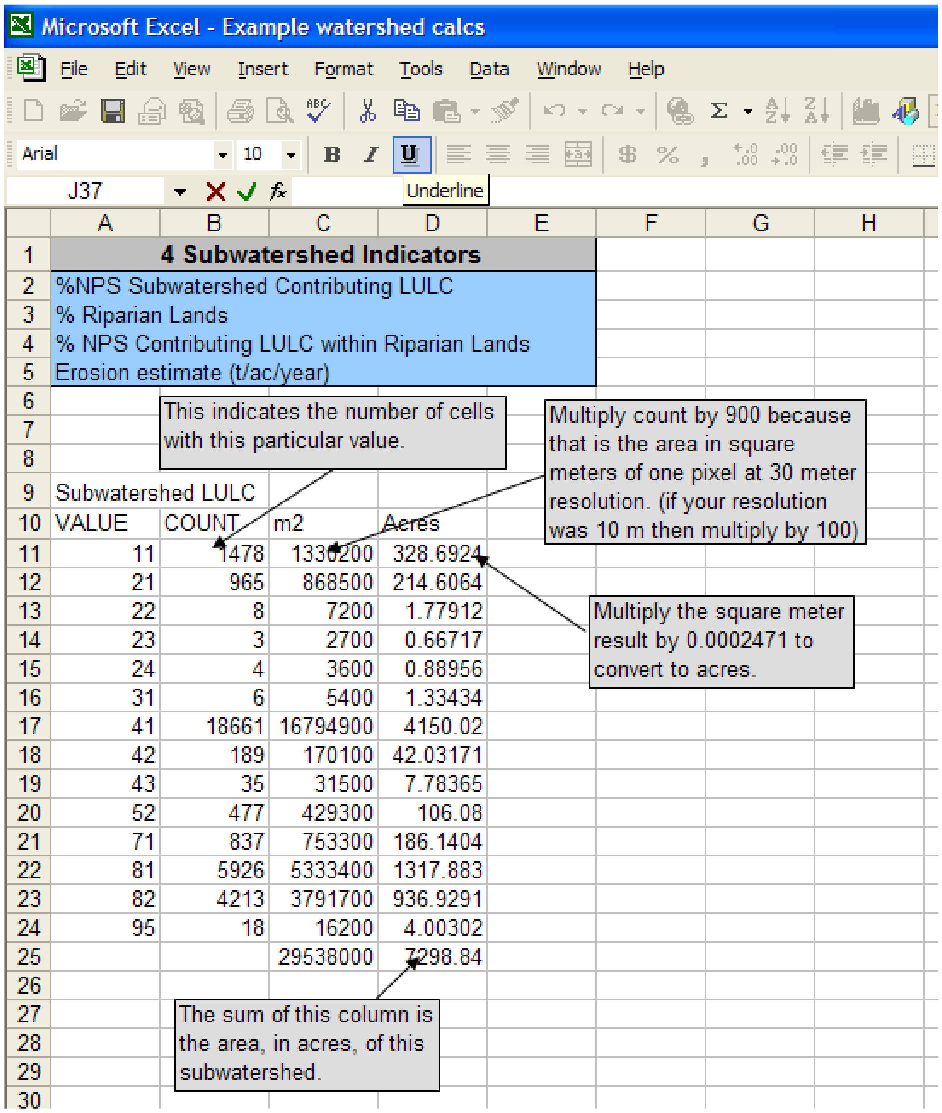
When the data is viewed in Excel, there will be two columns, Value and Count (Figure 7). Value is the number that correlates to the land use type and is not necessary information in this step, but will be in the next step. Sum the count column to get the total area. This total will be in number of grid cells. To convert this to acres first multiply the total by 900 square meters (the area of one grid cell). Next multiply the result by 0.0002471 (1 square meter = 0.0002471 acre), the result will be the acres of riparian area.



	A	B	C	D	E
32	Riparian (30m) LULC				
33	VALUE	COUNT	m2	Acres	
34	11	528	475200	117.4219	
35	21	32	28800	7.11648	
36	31	5	4500	1.11195	
37	41	2184	1965600	485.6998	
38	42	22	19800	4.89258	
39	43	4	3600	0.88956	
40	52	13	11700	2.89107	
41	71	15	13500	3.33585	
42	81	114	102600	25.35246	
43	82	129	116100	28.68831	
44	95	9	8100	2.00151	% Riparian Lands
45			2749500	679.4015	9.308349

Figure 7.

The area of the subwatershed is found by first extracting the land use layer, using the subwatershed of interest as a mask, as in the process described above (Figure 4). Second, the attribute table for the resulting grid layer is exported (Figure 6) as a dbf file. Copy the data in the resulting dbf file and paste in the excel file that already contains the riparian area. Be sure to label the data so they are not confused with the riparian data. Follow the same procedure described above to determine the total area in the riparian area (Figure 8).



4 Subwatershed Indicators			
%NPS Subwatershed Contributing LULC			
% Riparian Lands			
% NPS Contributing LULC within Riparian Lands			
Erosion estimate (t/ac/year)			
Subwatershed LULC			
VALUE	COUNT	m2	Acres
11	1478	1330200	328.6924
21	965	868500	214.6064
22	8	7200	1.77912
23	3	2700	0.66717
24	4	3600	0.88956
31	6	5400	1.33434
41	18661	16794900	4150.02
42	189	170100	42.03171
43	35	31500	7.78365
52	477	429300	106.08
71	837	753300	186.1404
81	5926	5333400	1317.883
82	4213	3791700	936.9291
95	18	16200	4.00302
		29538000	7298.84

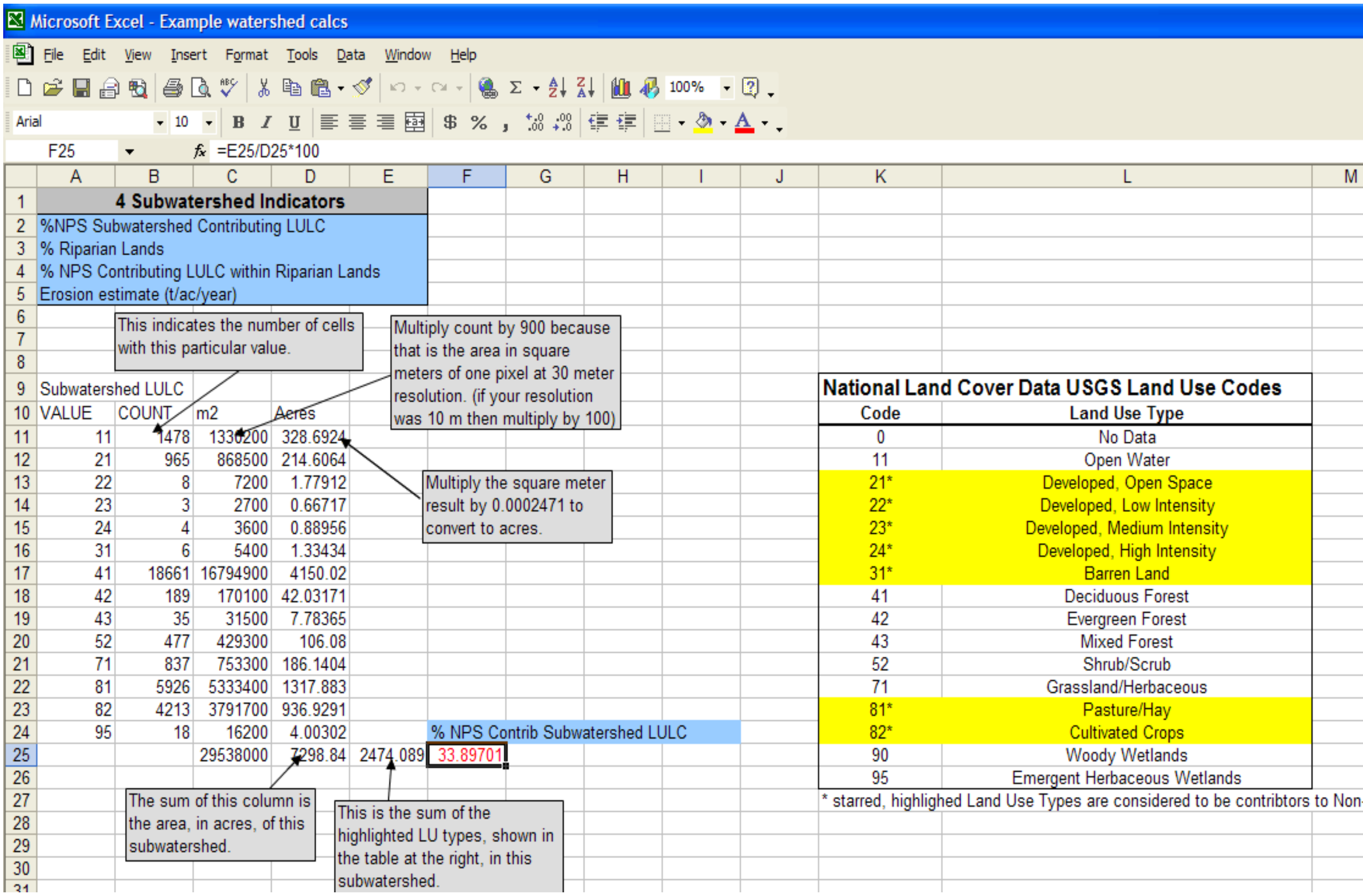
Figure 8.

Once the area of both the riparian areas and the subwatershed are calculated plug the numbers into the above equation and the result will be the proportion of riparian areas in the selected subwatershed.

B) % NPS Contributing LULC Subwatershed

*(Area of Nonpoint source pollution (NPS) contributing land uses in subwatershed / Total subwatershed area) *100 = % NPS Contributing LULC Subwatershed*

To determine the proportion of NPS contributing LULC in the subwatersheds, data previously exported to excel from the subwatershed land use is used. The land use types that contribute to nonpoint source pollution (NPS) are highlighted in the table in Figure 9. Calculate the percentage of contributing land uses by dividing the total area of NPS contributing LULC in the subwatershed by the total subwatershed area, which was calculated in the previous step, and multiply by 100.



	A	B	C	D	E	F
1	4 Subwatershed Indicators					
2	%NPS Subwatershed Contributing LULC					
3	% Riparian Lands					
4	% NPS Contributing LULC within Riparian Lands					
5	Erosion estimate (t/ac/year)					
9	Subwatershed LULC					
10	VALUE	COUNT	m2	Acres		
11	11	1478	1330200	328.6924		
12	21	965	868500	214.6064		
13	22	8	7200	1.77912		
14	23	3	2700	0.66717		
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22	81	5926	5333400	1317.883		
23	82	4213	3791700	936.9291		
24	95	18	16200	4.00302		% NPS Contrib Subwatershed LULC
25			29538000	7298.84	2474.089	33.89701

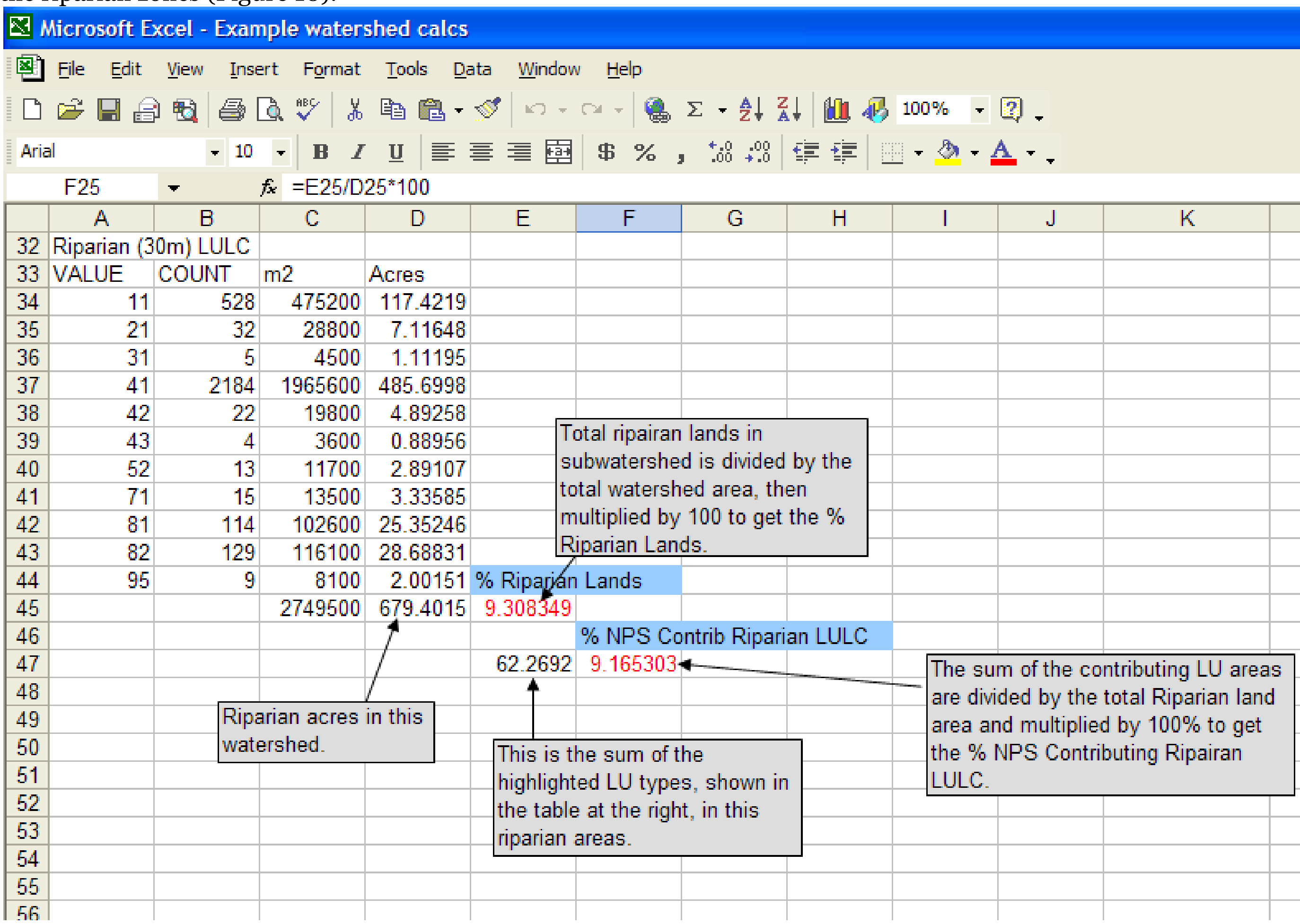
National Land Cover Data USGS Land Use Codes	
Code	Land Use Type
0	No Data
11	Open Water
21*	Developed, Open Space
22*	Developed, Low Intensity
23*	Developed, Medium Intensity
24*	Developed, High Intensity
31*	Barren Land
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
52	Shrub/Scrub
71	Grassland/Herbaceous
81*	Pasture/Hay
82*	Cultivated Crops
90	Woody Wetlands
95	Emergent Herbaceous Wetlands

Figure 9

C) %NPS Contributing LULC in Riparian Lands

*(Total area of NPS contributing LULC in riparian zone / Total area of riparian zone) * 100 = % NPS Contributing LULC in Riparian Lands*

To determine the values for the third indicator of subwatershed prioritization, the LULC layer that was previously clipped to the stream buffers and exported is used. The land use types that contribute to nonpoint source pollution (NPS) are highlighted in the table seen in Figure 9. Sum the total nonpoint source pollution areas within the stream buffers and divide by the total area of the riparian lands, this has been calculated in a previous step, and multiply by 100 to derive the percent contributing LULC in the riparian zones (Figure 10).



	A	B	C	D	E	F
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33	VALUE	COUNT	m2	Acres		
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39	43	4	3600	0.88956		
40	52	13	11700	2.89107		
41	71	15	13500	3.33585		
42	81	114	102600	25.35246		
43	82	129	116100	28.68831		
44	95	9	8100	2.00151	% Riparian Lands	
45			2749500	679.4015	9.308349	
46						% NPS Contrib Riparian LULC
47					62.2692	9.165303

Figure 10.

D) Average Annual Soil Loss (RUSLE) (Renard et. al)
The Revised Universal Soil Loss Equation (RUSLE) was used to calculate annual soil loss from the watersheds using ArcGIS 9.x software and the Spatial Analyst extension.

The RUSLE equation is:
A=RKLSCP
Where;
A= average annual soil loss (tons/acre/year)
R= rainfall and runoff erodibility index for a given location
K= soil erodibility factor
L=Slope length factor
S= Slope steepness factor
C= cover and management factor
P= conservation or support practice factor
(Renard et. al)

The good news is that R, and P are both constants. The R values can be found in Figure 11 or Appendix A.

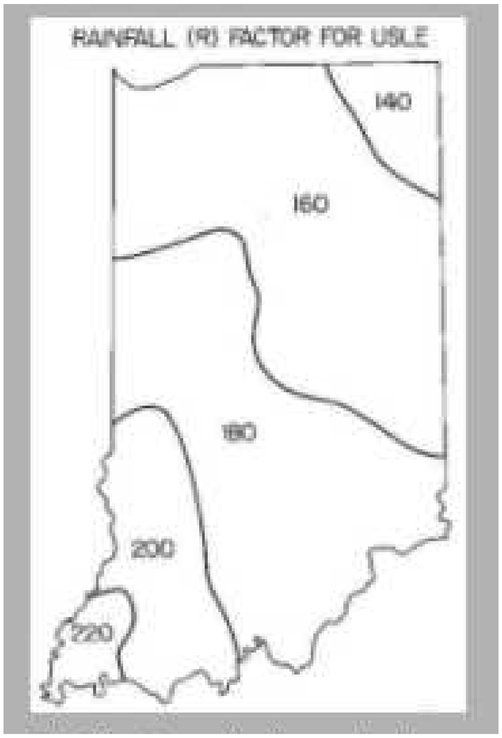


Figure 11. R factor map for Indiana for use in USLE and RUSLE models.

P ranges from 0-1, a 1 indicates that no conservation practices such as, filter strips, buffers, grassed waterways, ect…, are in place. We will assume a P of 1 although it is known that there are some conservation practices in place throughout the watershed. With this in mind, it is assumed that the results will be somewhat overestimated.

The C factor will be derived from the land use layer that has been clipped to the watershed. Reclassify the LULC layer attribute table to have the values shown in Table 2 and then create a layer from that (Figure 12). To do this open the "Spatial Analyst Tools" , then go to the "Reclass" tool. Under that tool is the "Reclassify" function, click this and the reclass wizard will appear (Figure 12).

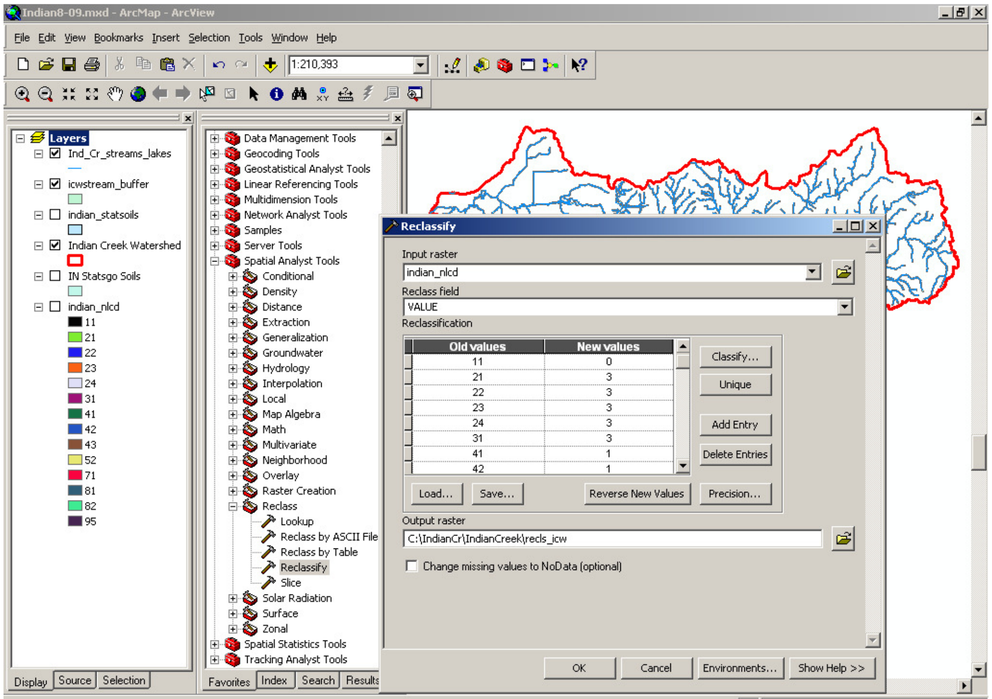


Figure 12.

Table 2. Land use values to be used for the RUSLE C factor.

Land Use	RUSLE C
Row Crops	0.24
Pasture/Grass	0.05
Forest	0.01
Urban, Non-Vegetated, No Data	0.03
Farmstead	0.04
Wetland, Water	0.00

Unfortunately when reclassifying, only integers can be entered, therefore they were entered as 24, 5 etc. then, multiplied by 0.01 using raster calculator to get the actual values (Figures 14-17). To access the raster calculator, first make sure that the spatial analyst extension is on (Figure 13).

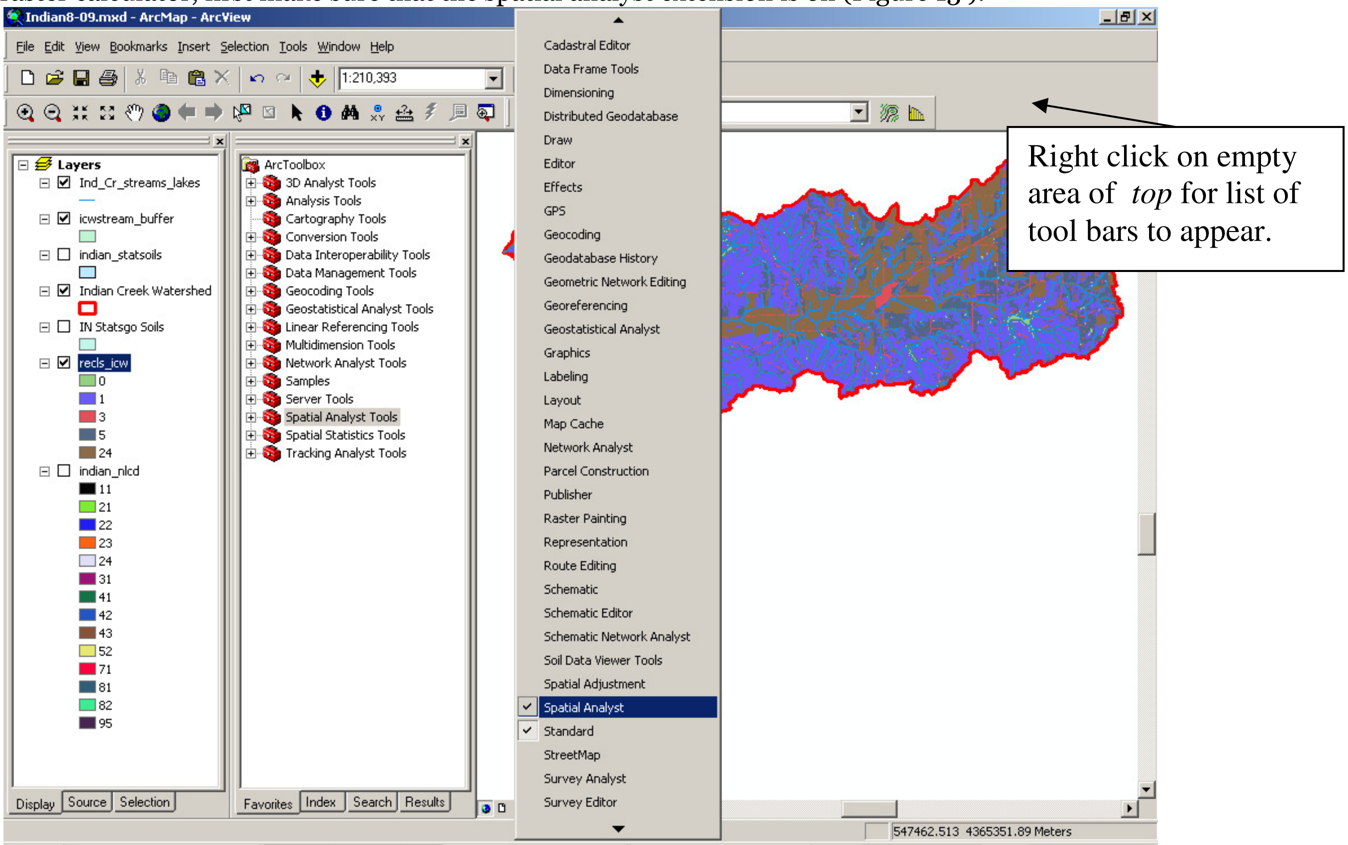


Figure 13.

Then set the working directory to the folder that all the data for the project is going in otherwise all the calculations in raster calculator will go into a temporary file and you will not be able to find them later on (Figures 14 & 15).

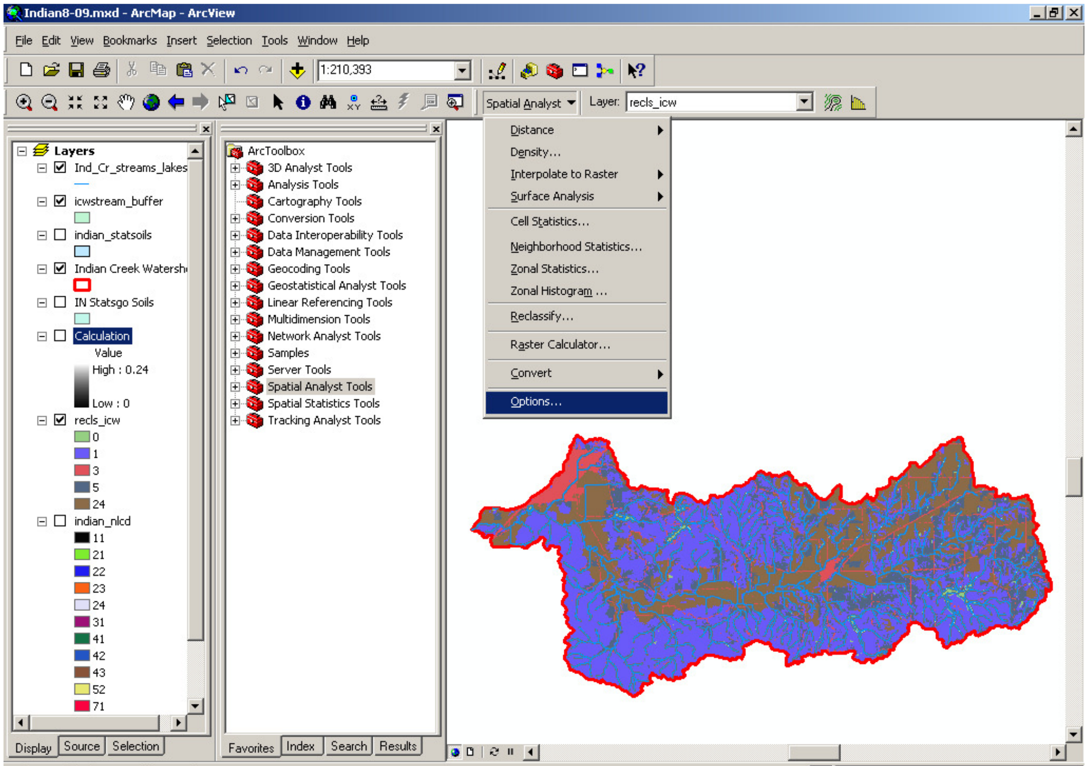


Figure 14.

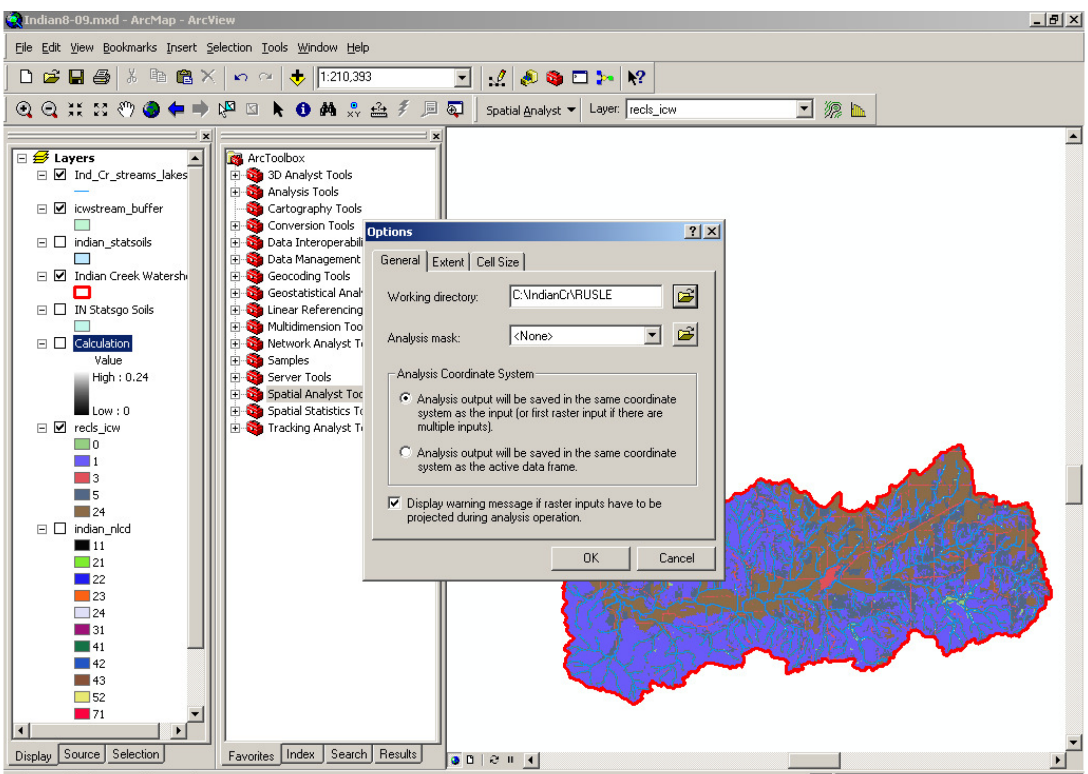


Figure 15. Assigning a working directory to raster calculator so that layers that are created are not saved to a temporary file that will be difficult to find later on.

Go to raster calculator on the spatial analyst toolbar (Figure 16).

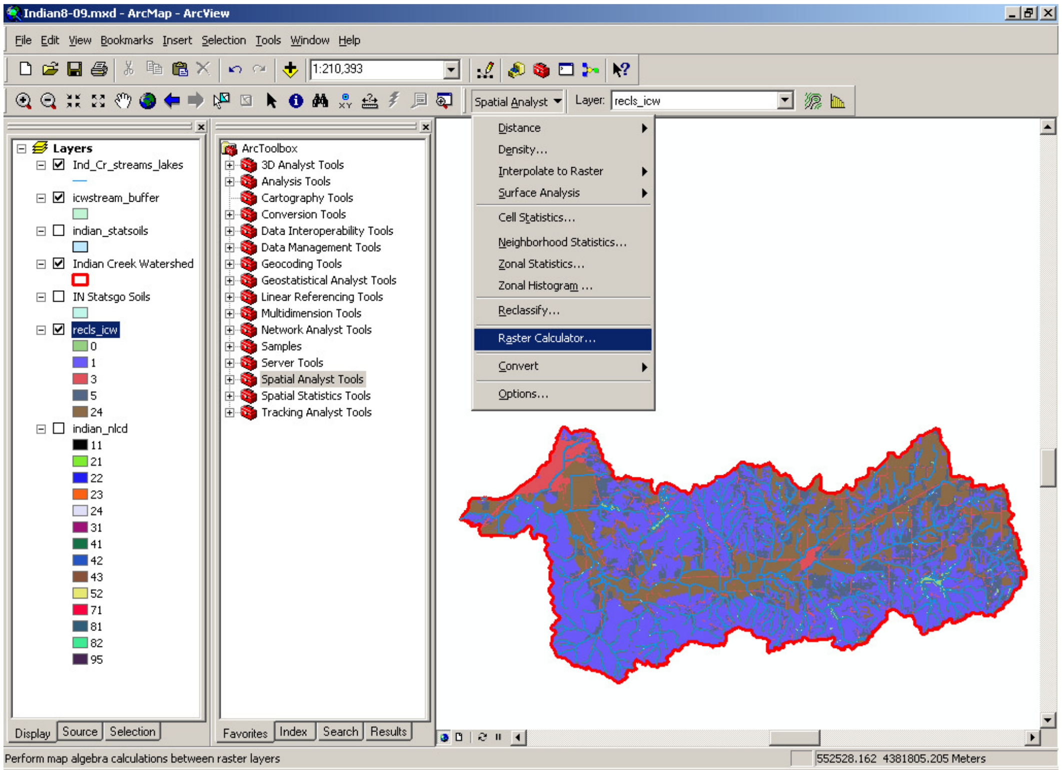


Figure 16.

In the raster calculator take the reclassified landuse and multiply it by 0.01 and click evaluate (Figure 17). Be sure to rename the layer “C-Value” in the map document so you know which layer to use for the RUSLE calculations.

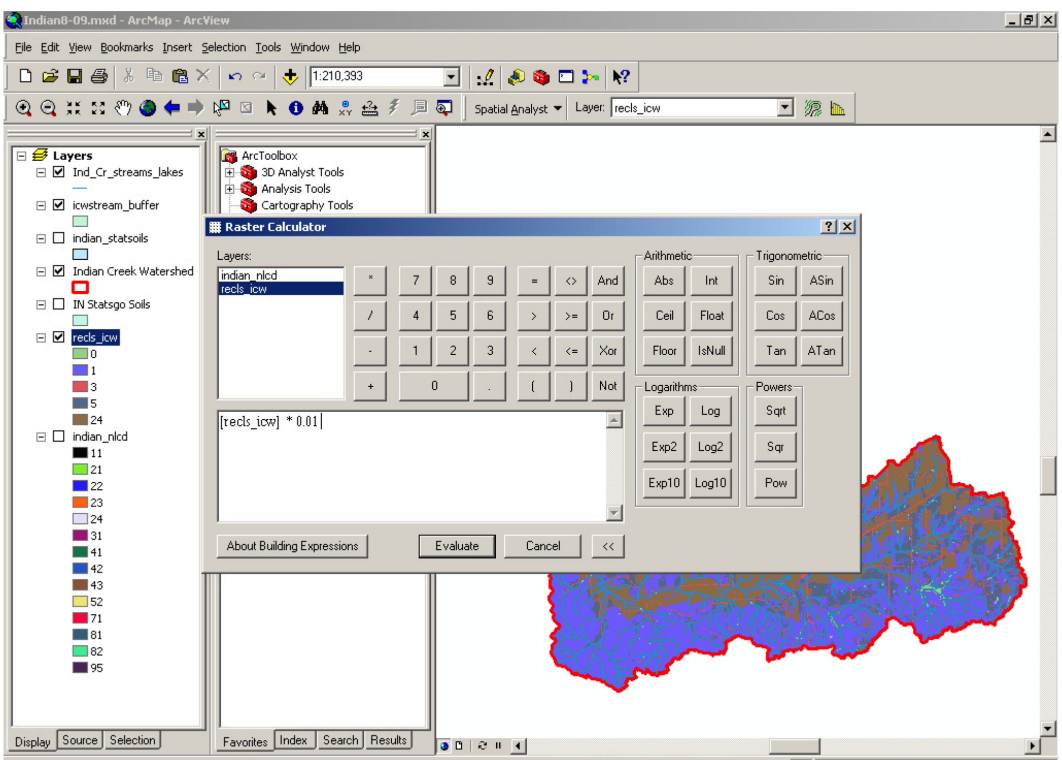


Figure 17.

STATSGO Soils

To derive the K factor or erodibility, first clip the soils layer to the watershed (Figure 2) . Additional soils information for the STATSGO layers is contained in separate attribute tables. The field that contains erodiblity information is labeled Kffact. This is the field that the STATSGO user manual (USDA NRCS 1994) suggest be used when calculating RUSLE. The table named layer.dbf contains the soil erodibility data. This table is added to the map project (Figure 18).

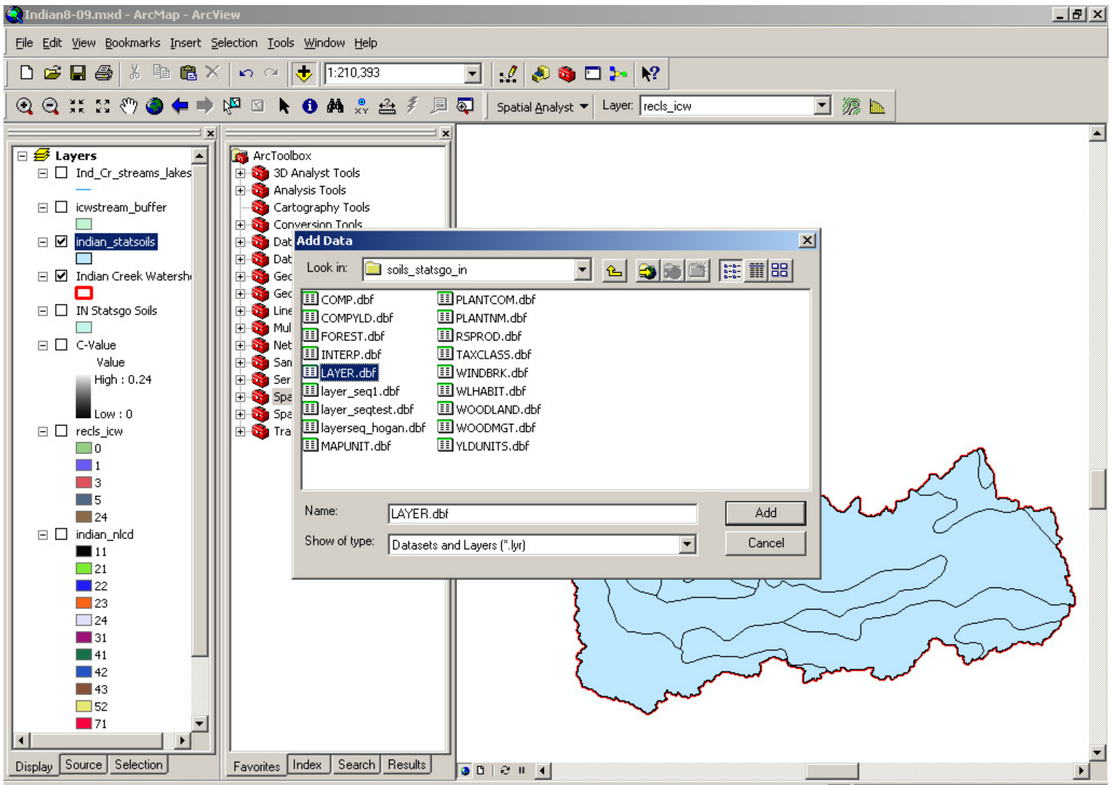


Figure 18.

Since only the top soil layer (layernum 1) and the primary soil sequence (seqnum 1) are of interest these are queried out. The selected records should then be exported and added to the project as a new table, in this case the table was named seq1layer1 (Figures 19 -21). Areas without a Kffact value, usually urban areas, need to be edited to display a value of 0.03, unless they are water then they need to be a 0. This must be done before joining the tables. This can be accomplished by displaying the attribute table and then activating the editor mode for that table and simply inserting the correct number. When the table edits are complete be sure to save the edits and close the editor.

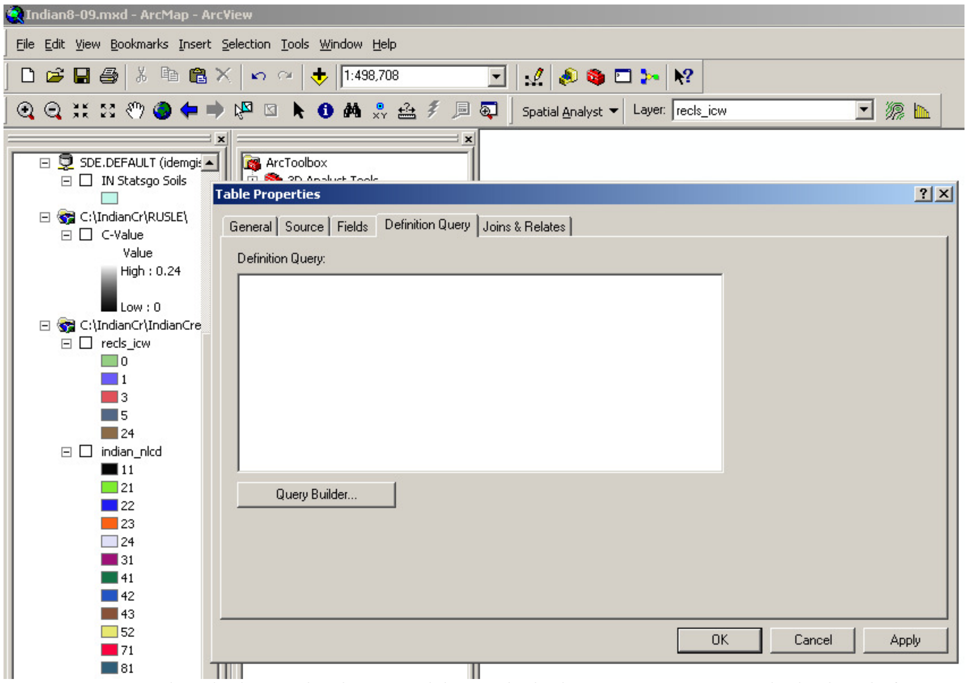


Figure 19. Right click on the layer table and click on properties. Click the definition & query tab, then click the query builder button.

In the query builder insert the follwing query; “SEQNUM” = 1 AND “LAYERNUM” = 1 and click ok.

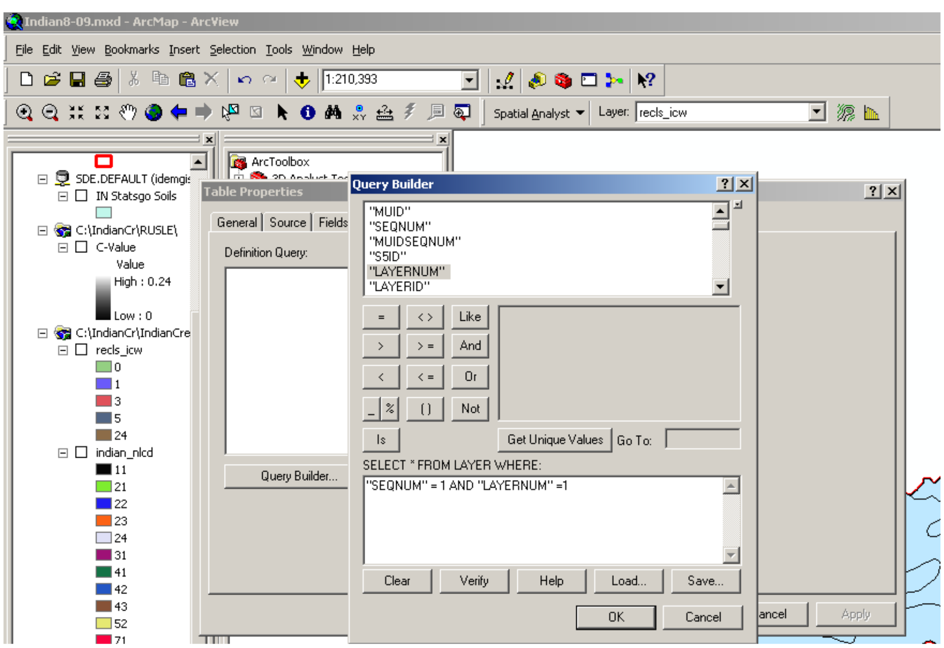


Figure 20.

This table that results from the query is then joined with the attribute table of the STATSGO soils layer using MUID as the joining field (Figure 21).
To join table data to the soils layer right click on the soils layer and click on “joins and relates” then from the resulting drop down menu click “join”. The join wizard will appear (Figure 21). Use the MUID field from the soil layer to be the joining field and the table created in the previous query. Under join options select “keep all records”, then click ok.

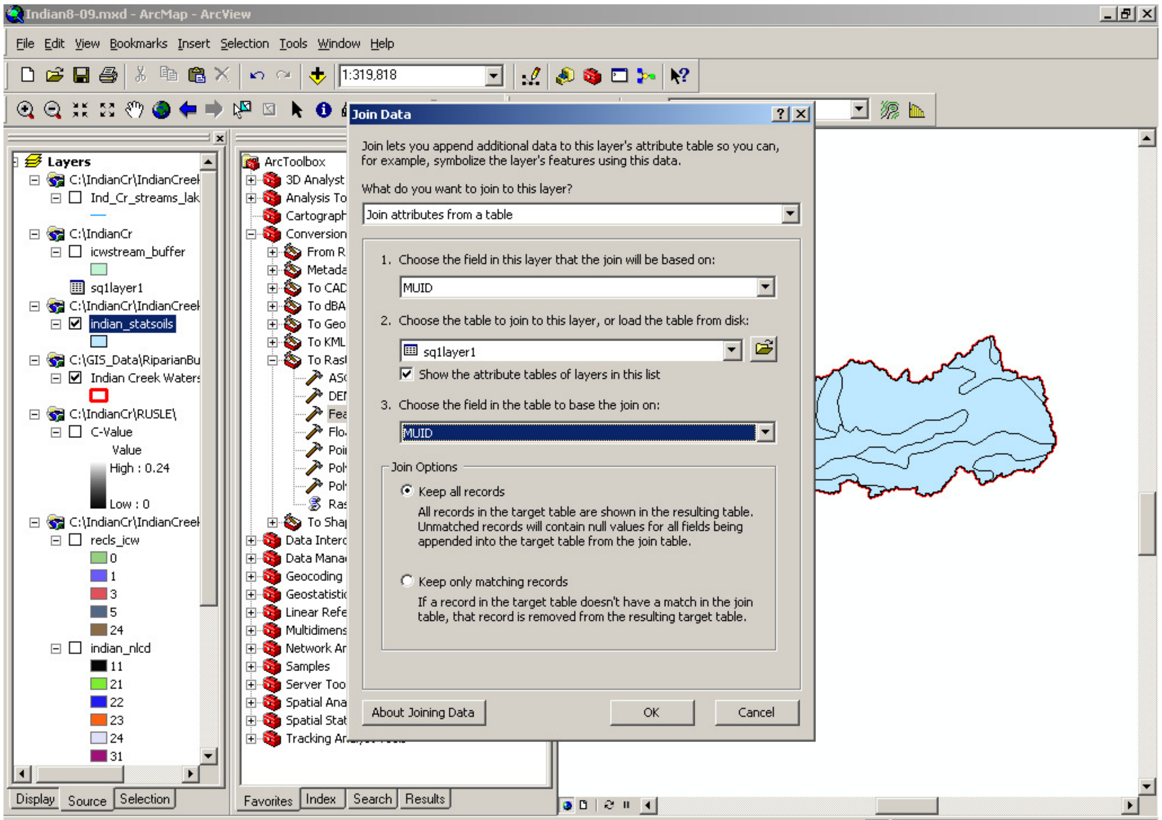


Figure 21.

If there are multiple counties within the watershed then K factors for every county in the watershed will need to be calculated. K factor layers created for each area will then need to be merged into one K factor layer (Figure 27). This layer then should be clipped down the specific watershed of interest.

The soil layer is a shape file that must be converted to a raster, with Kffact field selected when prompted for a field. When converting to a raster be sure to set the output cell size to the cell size of the rest of the data, in this case 30 meters (Figure 22).

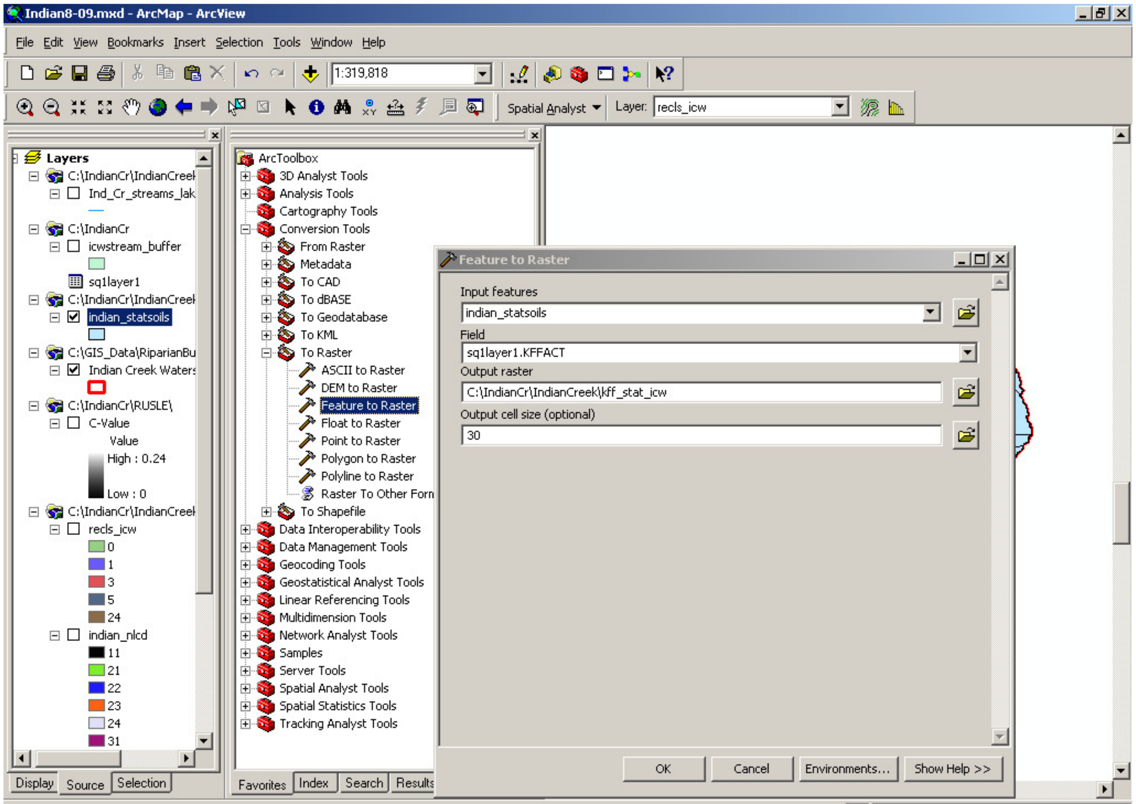


Figure 22.

SSURGO Soils

Download Soil Data Viewer. http://soildataviewer.nrcs.usda.gov/download.aspx

Before activating the Soil Viewer make sure that you have SSURGO map unit spatial layer added to ArcMap project. Data for the counties of interest can be downloaded from the NRCS Soil Data Mart. http://soildatamart.nrcs.usda.gov. Once installed, the Soil Data Viewer tools extension must be turned on. This is done by right clicking in the gray header in the opened ArcGIS window. A list of extensions will appear; check the Soil Data Viewer Tools (Figure 23). The icon for the soil data viewer will appear on the header (Figure 24).

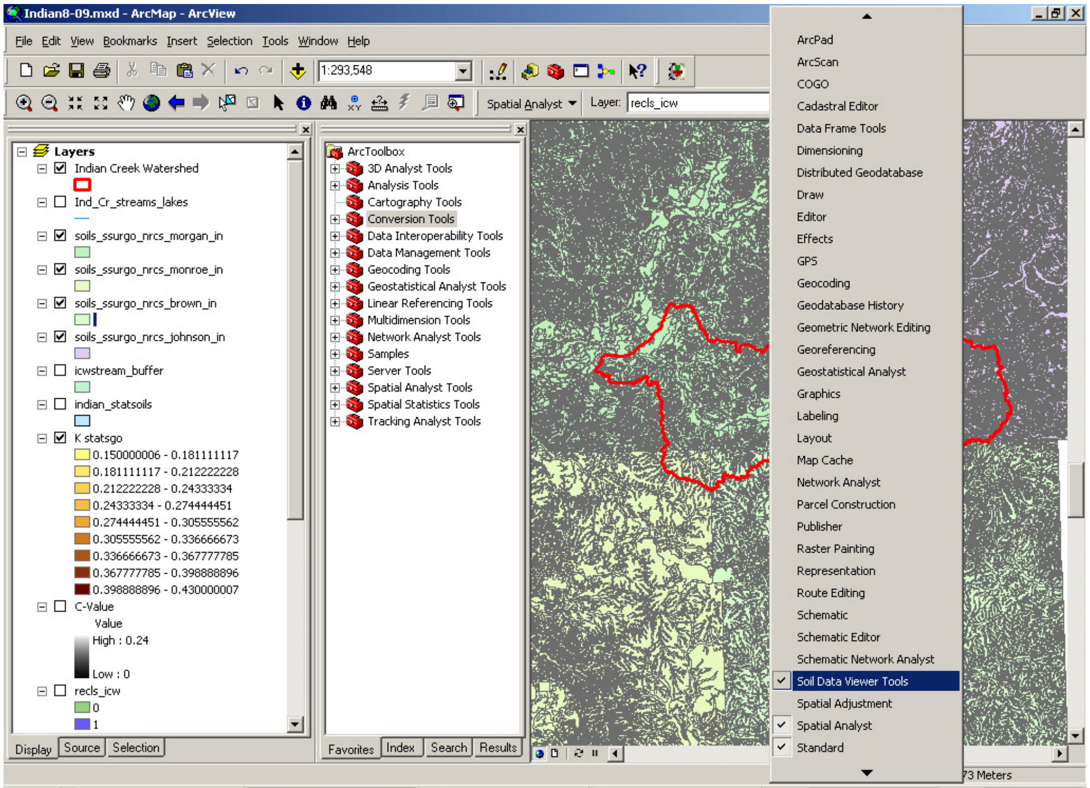


Figure 23.

Add the SSURGO map units spatial layer. After clicking on the Tool button it will ask what soils data to use, indicate where the tabular and spatial data are by selecting a "map layer source" (Figure 24).

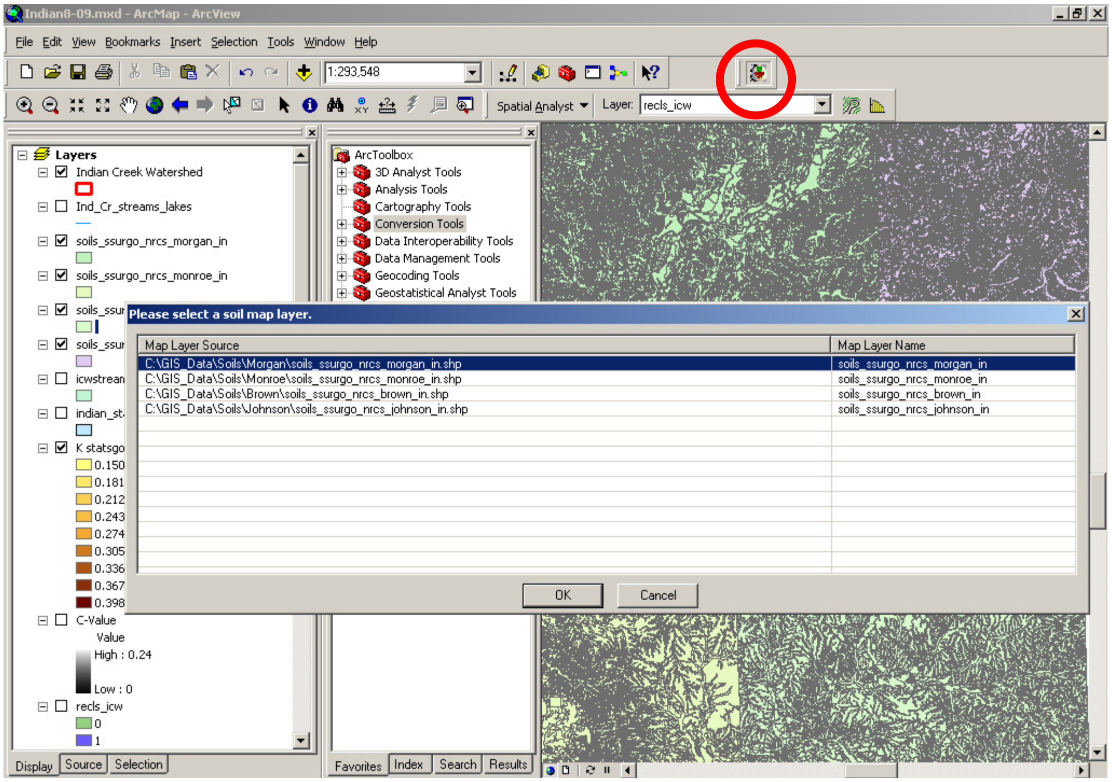


Figure 24.

For K factor you need to be in advanced mode (Figure 25).

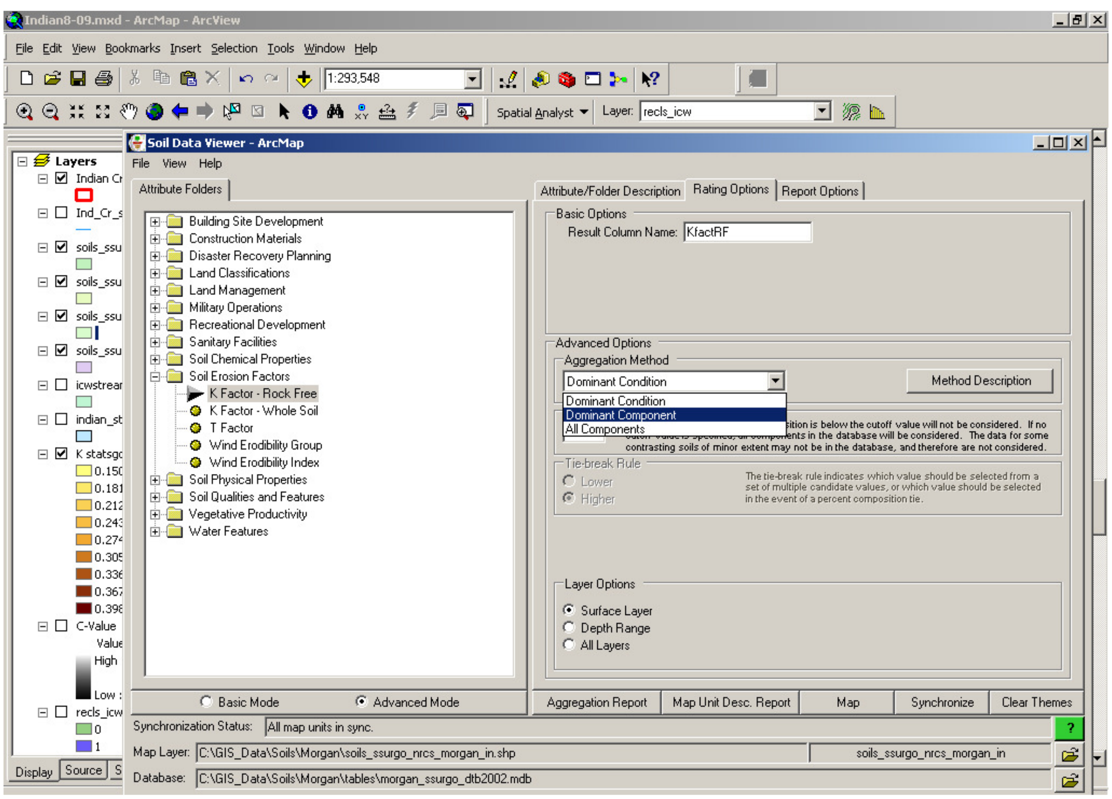


Figure 25.

Next, go to Soil Erosion factors and select K factor rock free. Click the Rating Options tab at the top, then use "Dominant component" for the Aggregation Method and "Surface layer" for the Layer Options. Then click the Report Options tab. Next, select “All Map Units”. Then click the “Map” tab at the bottom and a K factor shape file will be added to ArcGIS (Figure 26).

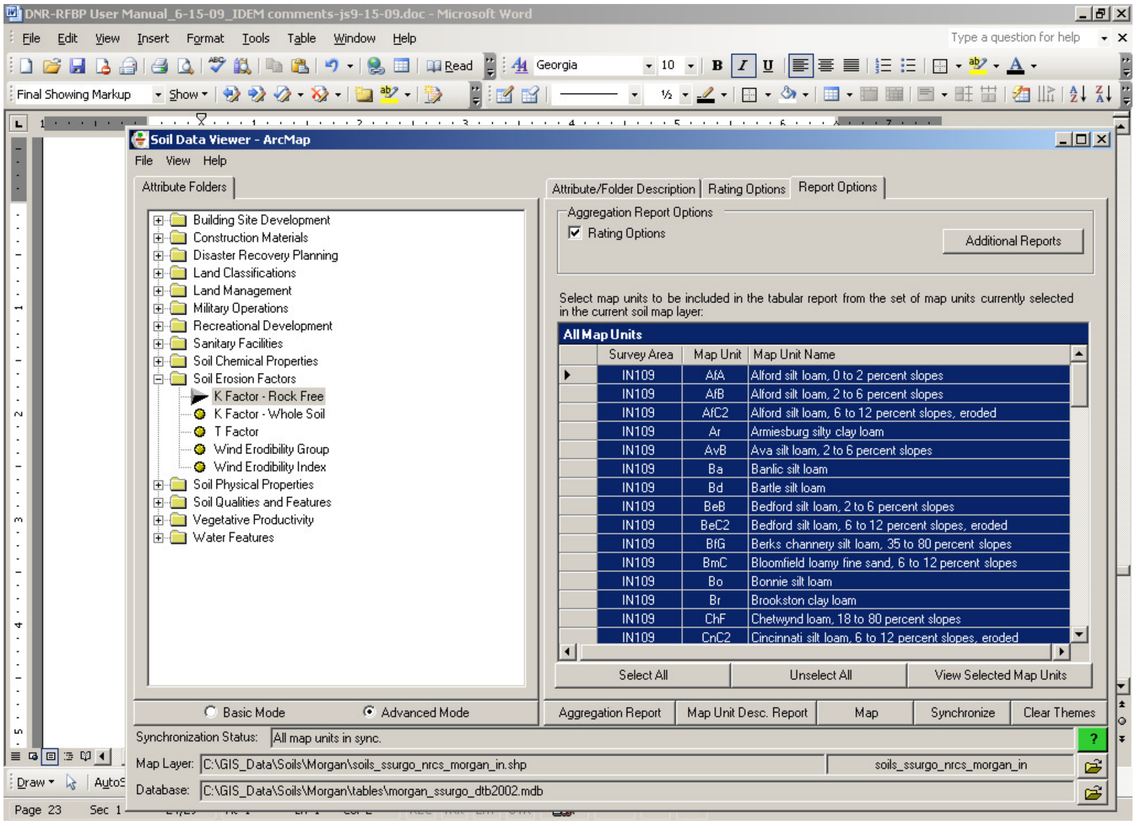


Figure 26.

If there are multiple counties within the watershed then K factors for every county in the watershed will need to be calculated. K factor layers created for each area will then need to be merged into one K factor layer (Figure 27). This layer then should be clipped down the specific watershed of interest. The resulting layer can then be manipulated. Turn on the editor to edit the soil attribute table. There will be some values lacking in the "K Factor" field. These are usually water areas and should be given a value of 0. If the area is urban give it a value of 0.3.

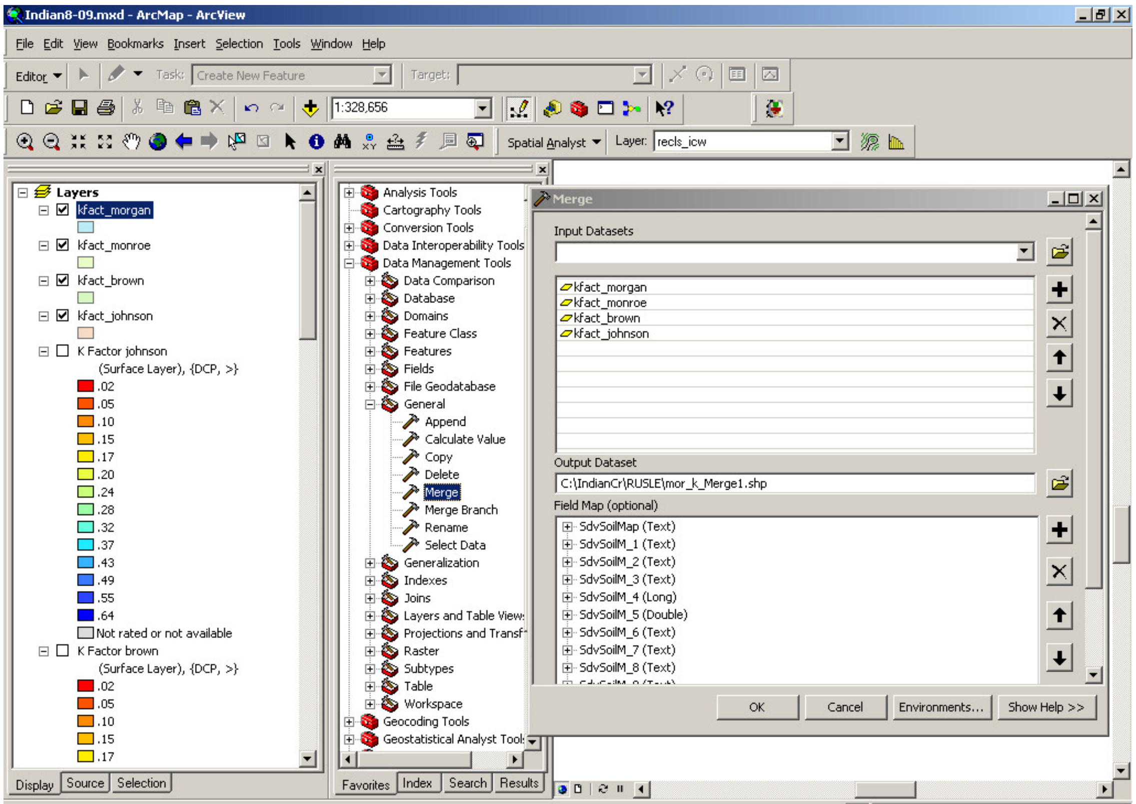


Figure 27.

The K factor field is in string, which will render in useless in a raster calculation so this field must be converted to a floating or number type. Under Options at the bottom right corner of the attribute table select add field (make sure the editor has been turned off and edits saved or this will not be activated) and select floating under the type box and click ok (Figure 28).

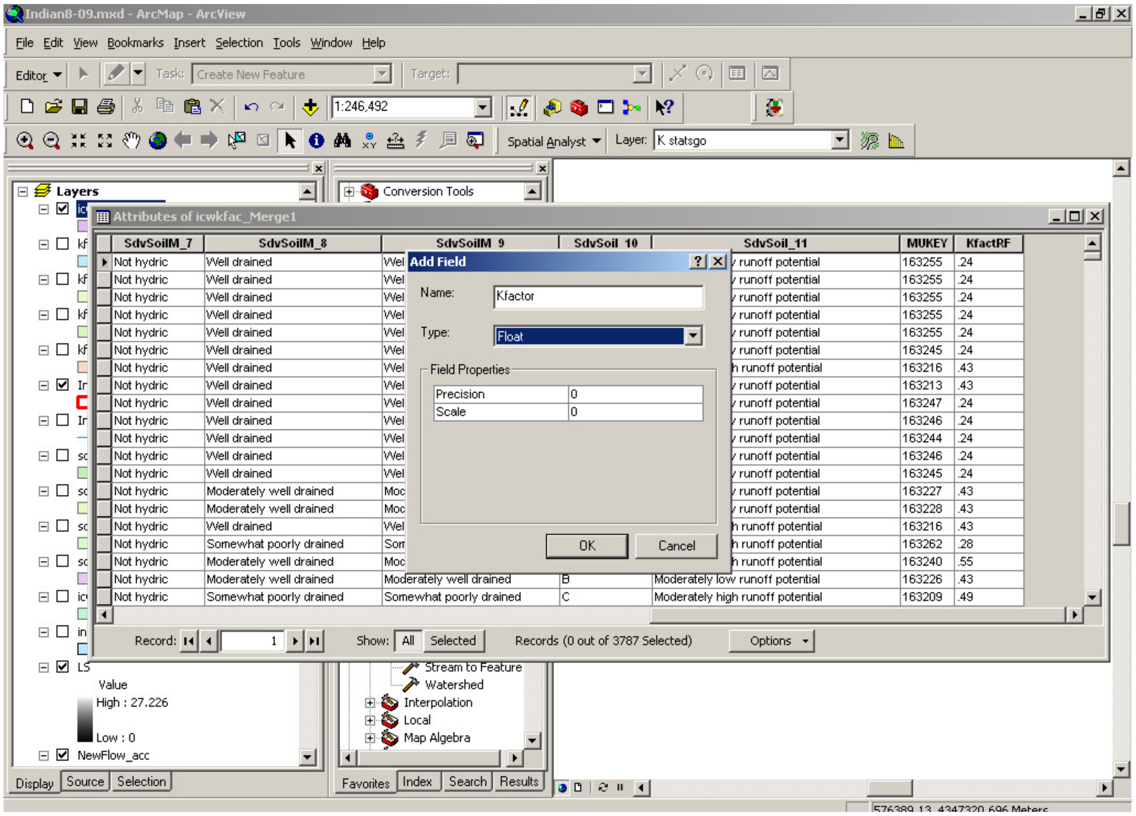


Figure 28.

Click the new field name and highlight the entire new field. Next right click on the new field label and go to the field calculator and click the original K factor field and that will make the original field equal to the new field, only the new field will be floating and thus workable for calculations (Figure 29).

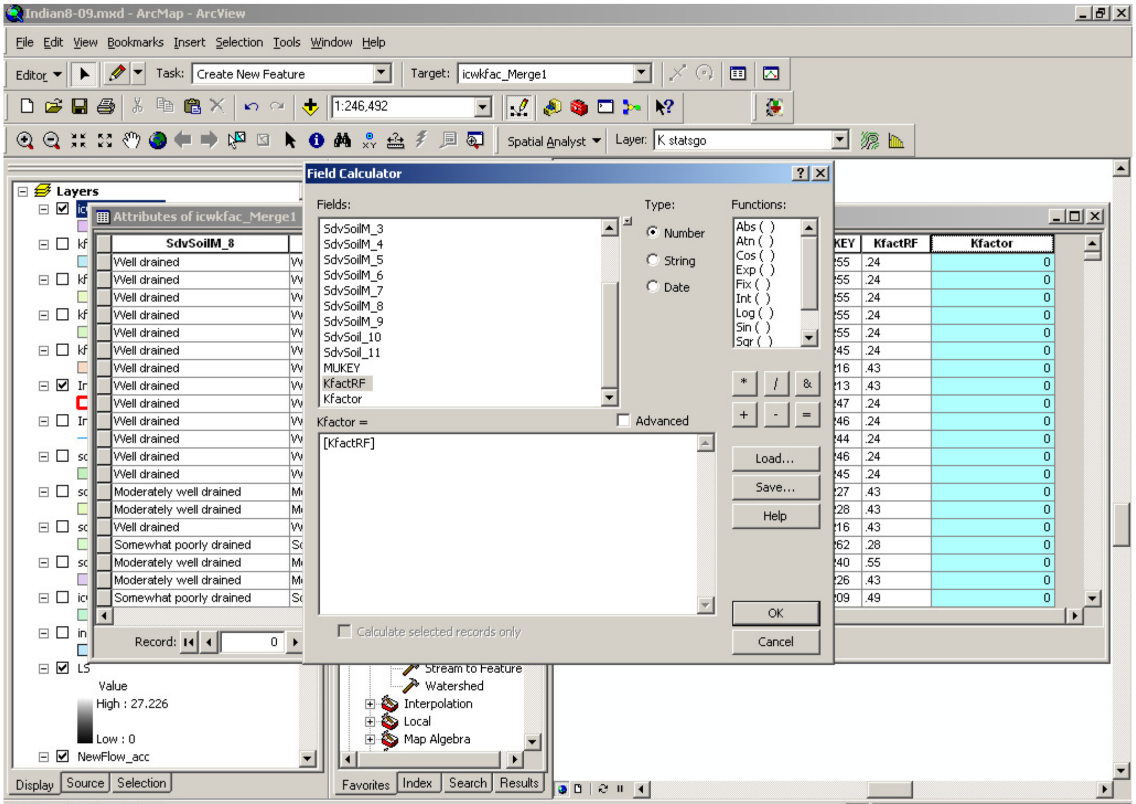


Figure 29.

Next, the K factor feature needs to be converted to a raster. Under conversion tools, go to "to raster" then click the feature to raster tool. Input the K factor layer and select the new K factor field; in the output cell size box enter the resolution of the rest of the data, in this case 30 meters. This will give you the K Factor layer needed to run the RUSLE analysis(Figure 30). Label the resulting layer as K factor.

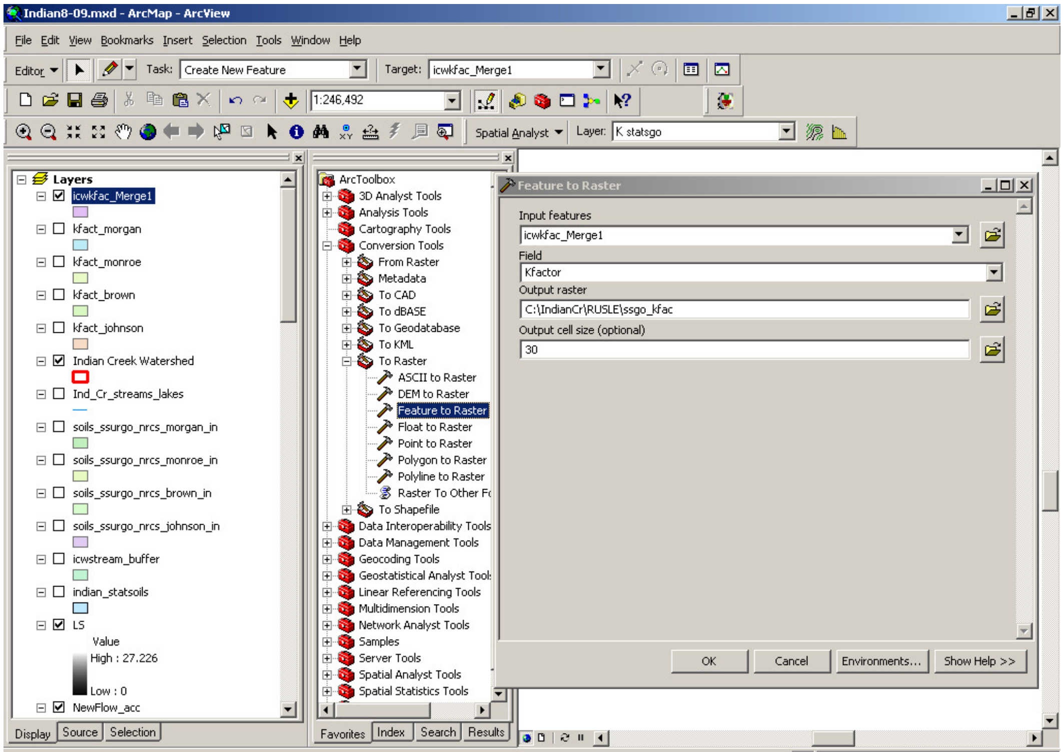


Figure 30.

The L and S layers are the most complicated and time consuming factors of the equation to create. They are generally combined to form the LS factor. The existing data used to calculate the LS factor is the Digital Elevation Model (DEM). Add the DEM to the project and extract it by the “mask” of the watershed as described previously (Figure 4). First, derive a slope layer from the DEM by going to the Surface portion of the Spatial Analyst toolbox. The slope layer needs to be in degrees (Figure 31). This layer will be used in an upcoming step.

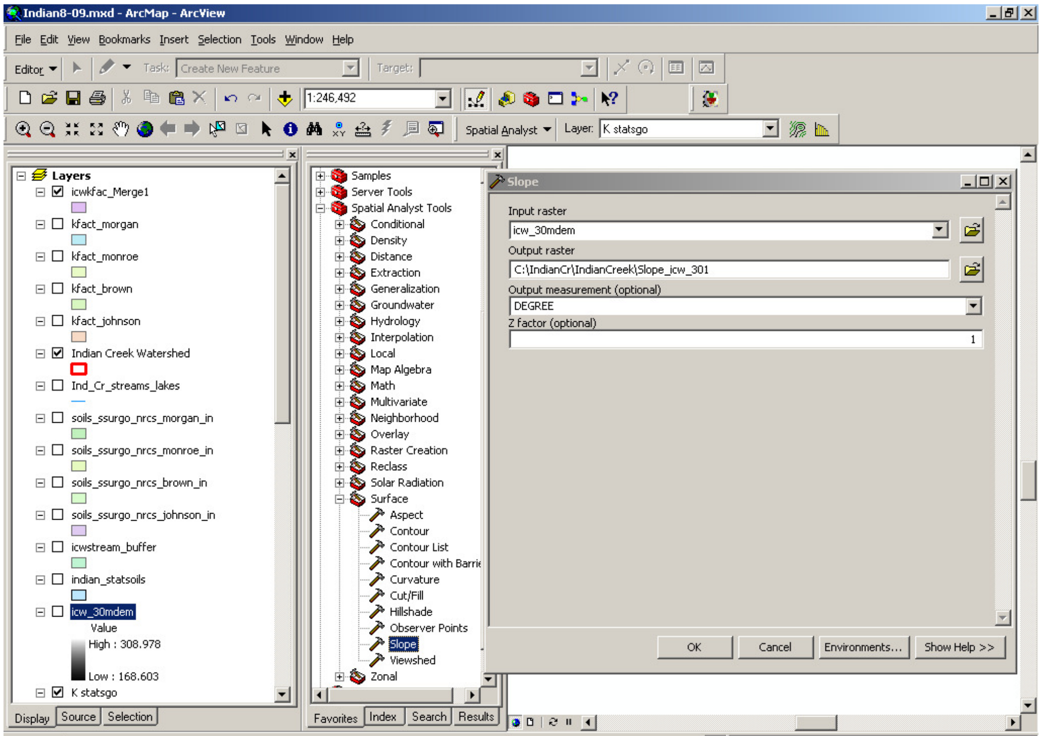


Figure 31.

Next, the DEM must be prepared for the LS calculation. Hydrology tools found under the Spatial Analyst toolbox are used to complete most of this factor. Under hydrology fill the sinks in the DEM (Figure 32). This will fill in small imperfections in the data and allowed the other steps to be more accurate.

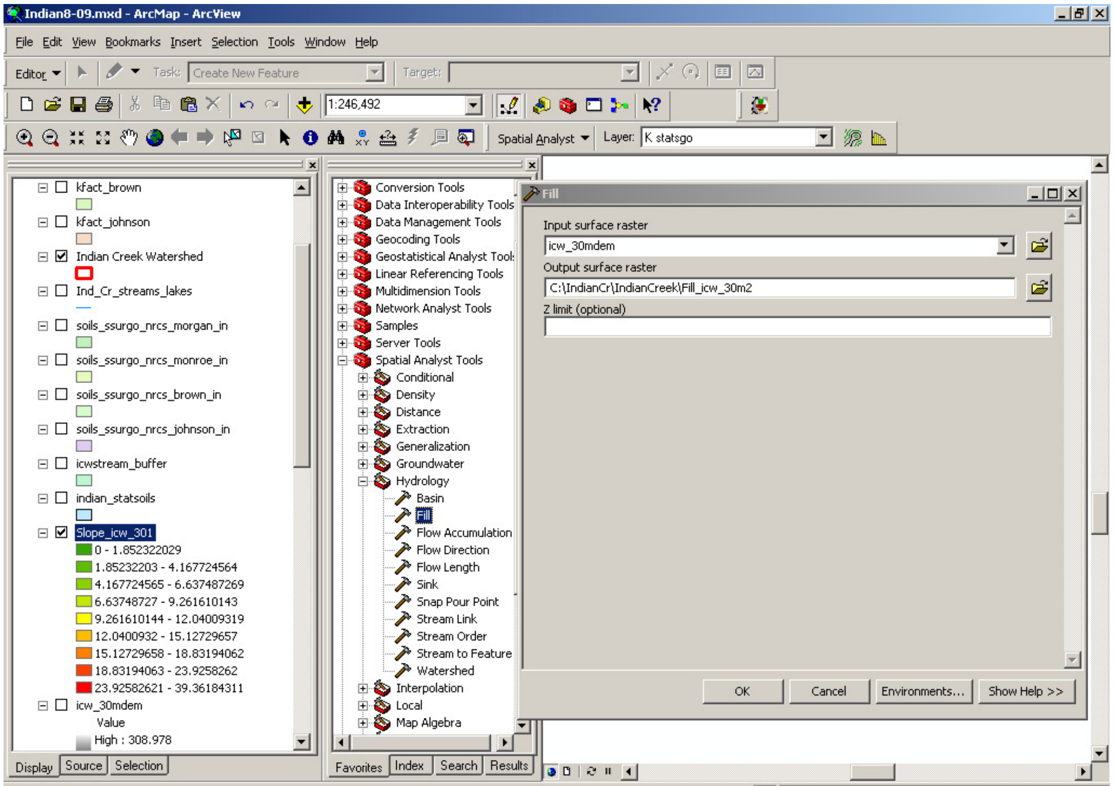
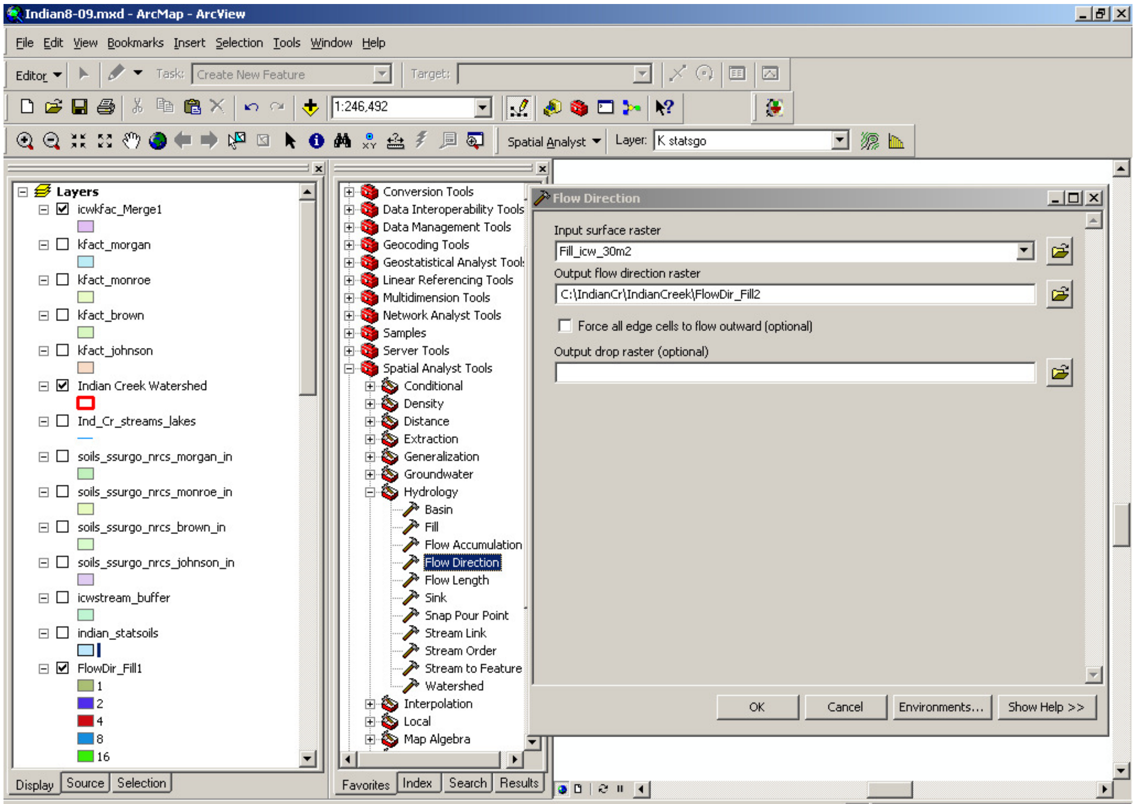


Figure 32.

Calculate flow direction using the filled DEM from the previous step. Under the “Spatial Analyst Tools” go to the “Hydrology” tools and select “Flow Direction” (Figure 33).



(Figure 33).

The flow accumulation is now calculated, it is located under the "Hydrology" tools as well. Insert the flow direction layer into the flow accumulation wizard to produce the flow accumulation layer (Figure 34).

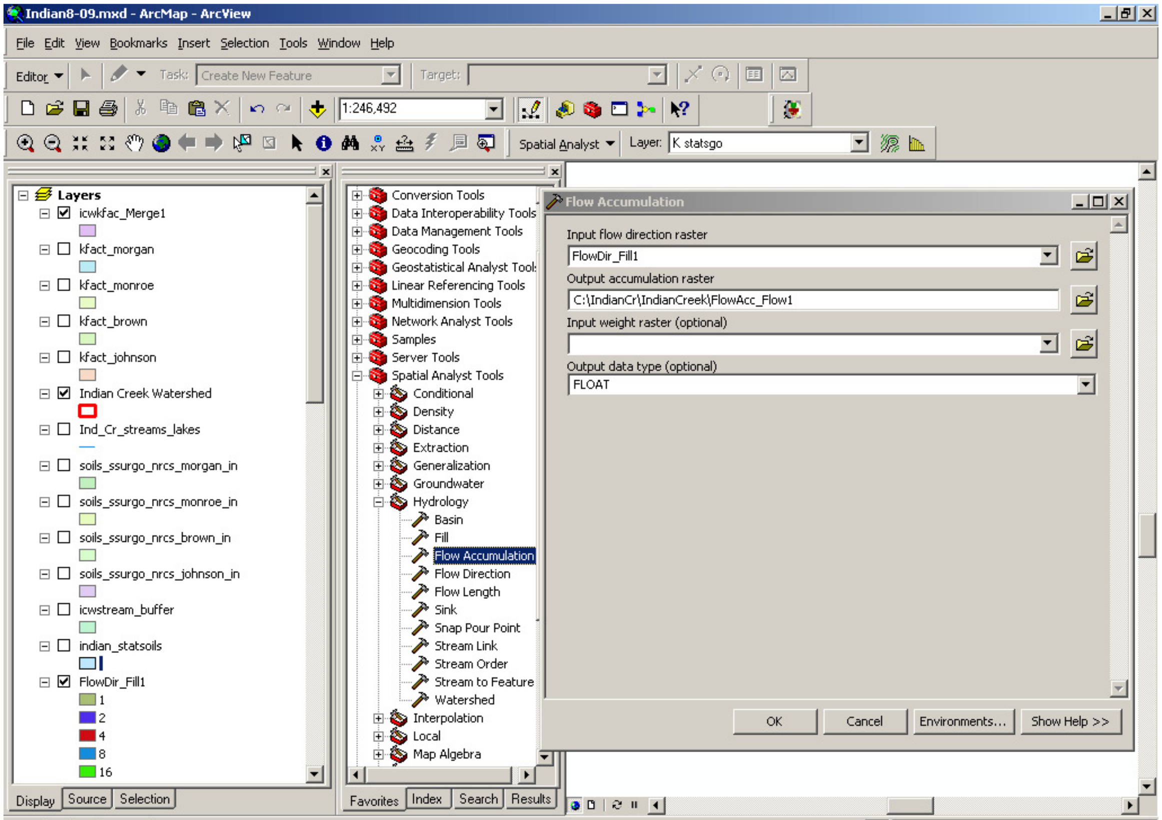


Figure 34.

Next limit the flow accumulation layer to 150 meters, as this is the distance to where sheet flow is still applicable. Do this using the raster calculator under the spatial analyst toolbar. If the resolution of the layers is about 30m then 150m would be about 5 grid cells. If grid cell size is different then there is a different number of maximum grid cells, for example; if the resolution is 10 m then the number of cells would be 15. Using the flow accumulation layer that was created the following steps were used in raster calculator. Figures 13 -16 show how to access raster calculator.

Step 1: (flow acc) > 5 = (calc 1) values are 0, 1. (Figure 34)
Step 2. (calc 1) * 5= (calc 2) values 0,5. (Figure 35)
Step 3. (flow acc)$\leq$ 5= (calc 3) values 0, 1; (Figure 36)
Step 4. (calc 3) * (flow acc)= (calc 4) values 0, 5. (Figure 37)
Step 5. (flow acc)=0= (calc 5) values 0,1. (Figure 38)
Step 6. (calc 2)+(calc 4)+(calc 5)= new flow acc , values should range from 1-5. (Figure 39)

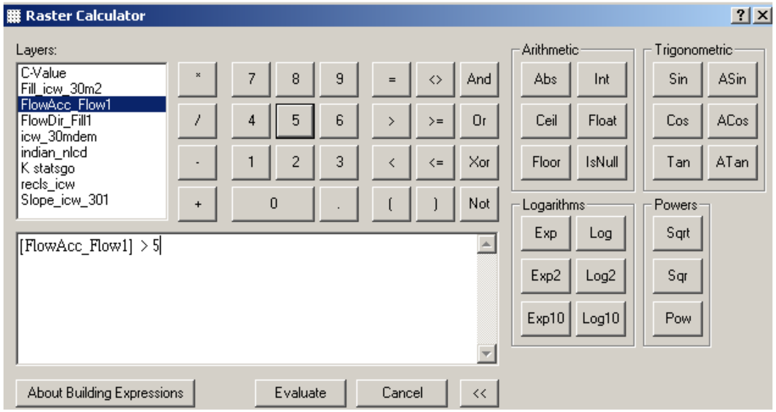


Figure 34.

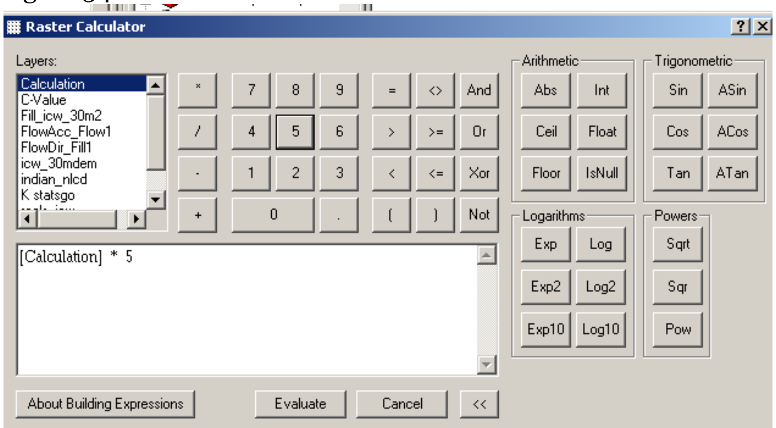


Figure 35.

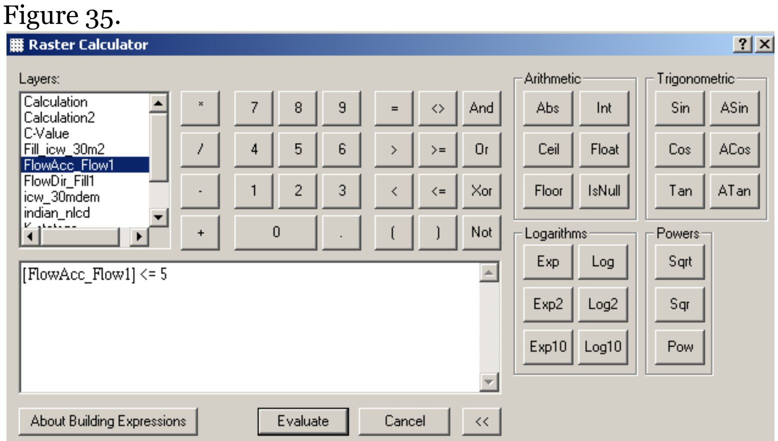


Figure 36.

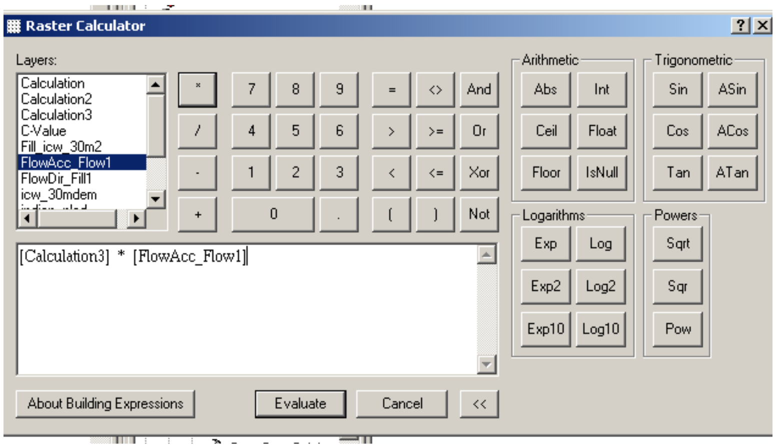


Figure 37.

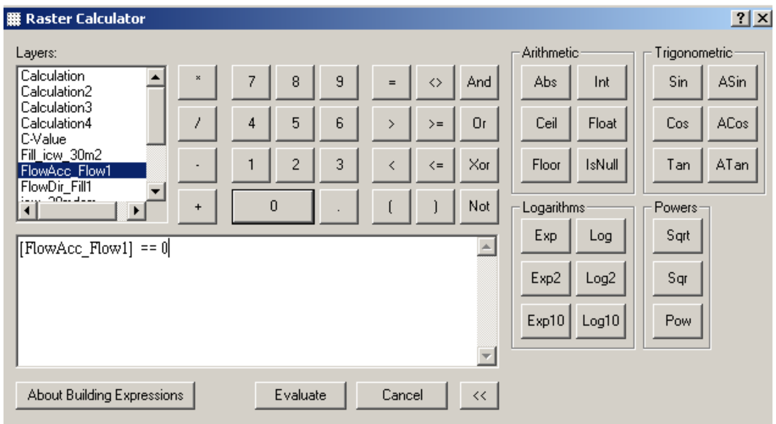


Figure 38.

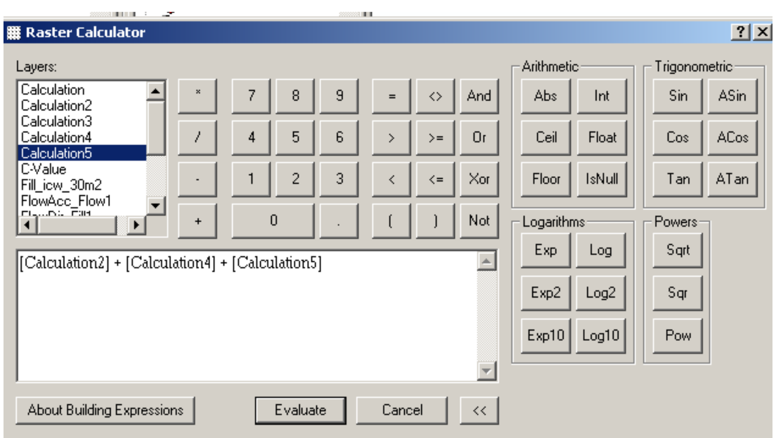


Figure 39. This calculation will produce the new flow accumulation layer, be sure to label as such.

The newly created flow accumulation layer and the previously created slope layer were inserted in the following equation that can be copied directly into the raster calculator dialog box. It is ***very important*** to make sure to have the spaces before and after the multiplication and division operators, you will save yourself much time and frustration if you remember this! If you do fail to enter the formula correctly you will get a syntax error message.

Pow([new_flowacc] * cell size / 22.1, .4) * Pow(Sin([slope] * .01745) / .09, 1.3)

The output of this equation is the LS layer, make sure to label it accordingly. In order to obtain the A, or annual soil loss, multiply the K, LS, C P and R layers in the raster calculator (Figure 40).

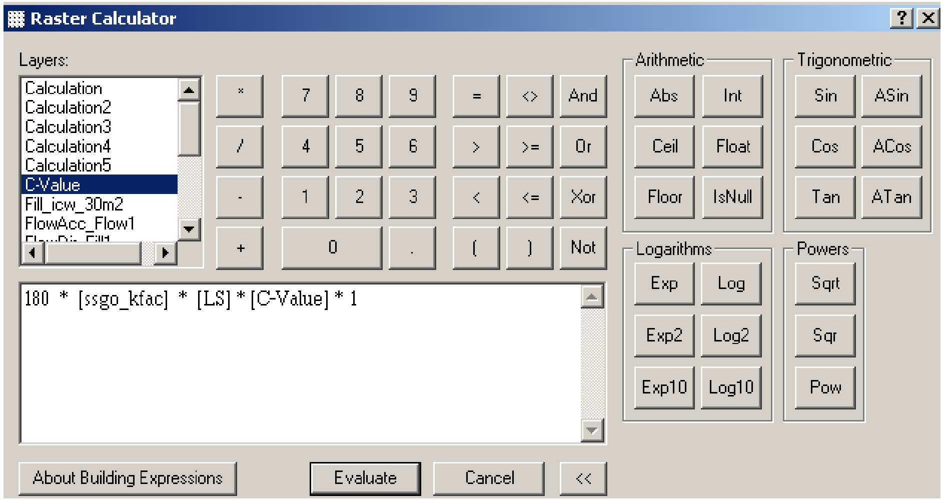


Figure 40.

The results are non integer and thus should be converted to integer and multiplied by 100 in order to view or edit the attribute table. Do this by using the integer tool in raster calculator (Figure 41).

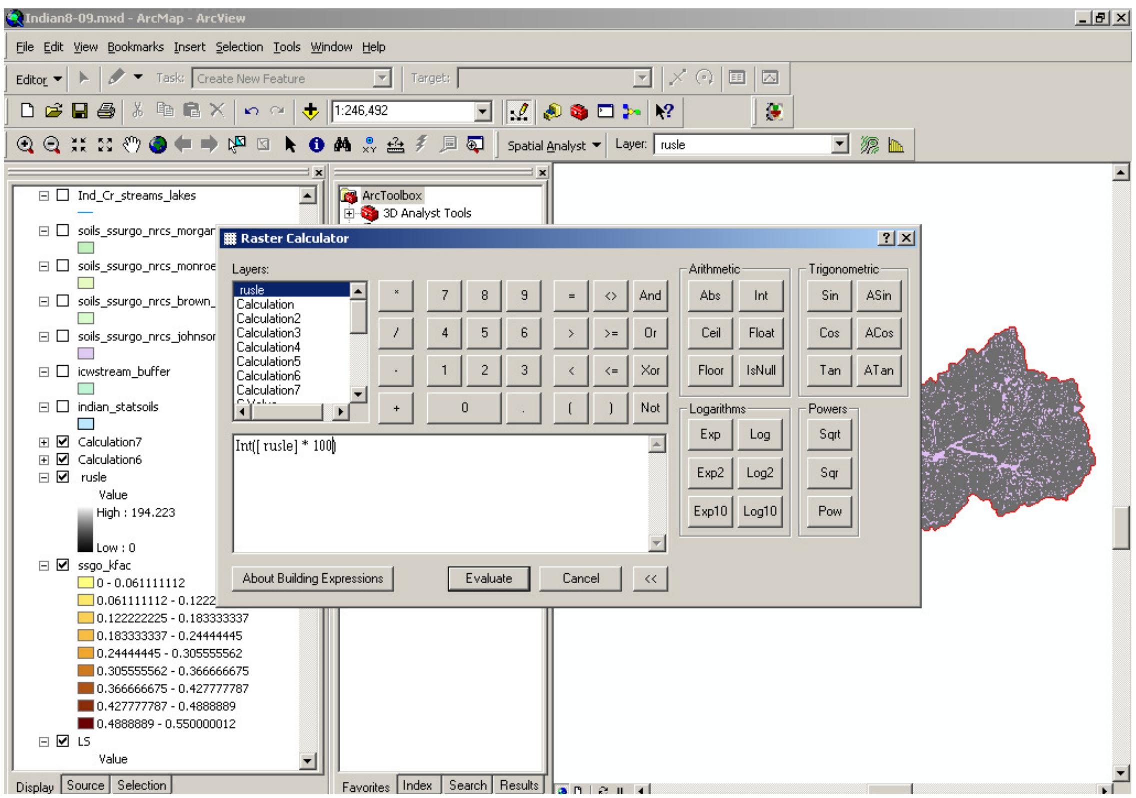


Figure 41.

The result will be in units of tons per acre per year. To find the average soil erosion for an area, the attribute table of the layer created by the above step was exported to excel and the value and count columns were multiplied and then summed. The sum was then divided by 100 and then is then divided by the area studied. Another way to find the mean soil erosion for an area is to double click on the layer and bring up the menu (the data must be in integers here or the attribute table isn't available). Then click on layer then go to layer properties. From there click the symbology tab, then the classify button and find the mean in the statistics table.

4.3.2 Stream Reach

For stream reaches methods similar to subwatershed analysis are used. Place a 30 meter buffer, or the width of your choosing, around the streams. Then, cut the buffer into approximately 800 meter reaches using the cut polygon option under editor (Figures 42 – 48) .

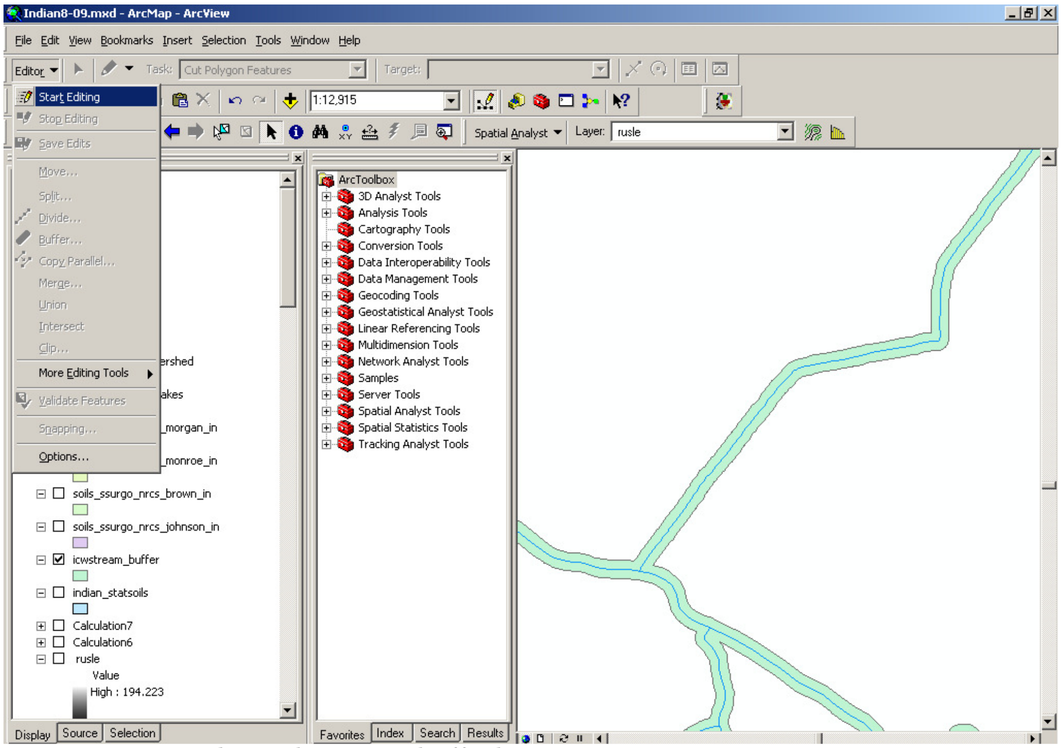


Figure 42. Start editing the stream buffer layer.

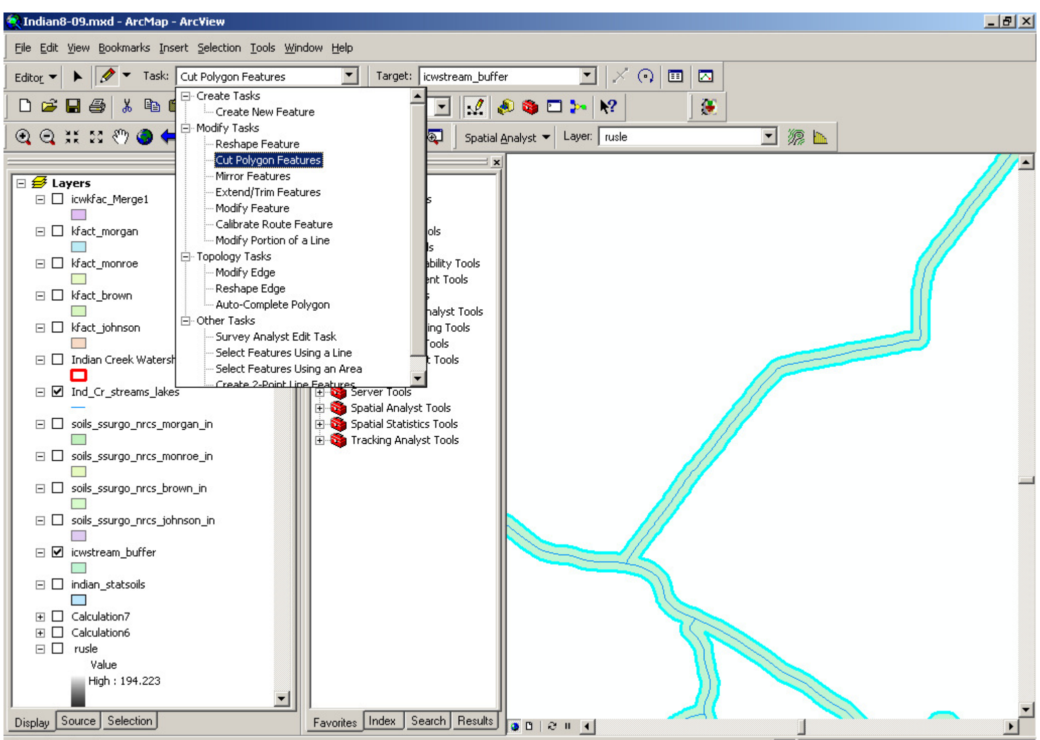


Figure 43. Under editing tasks select cut polygon features.

Figure 44.

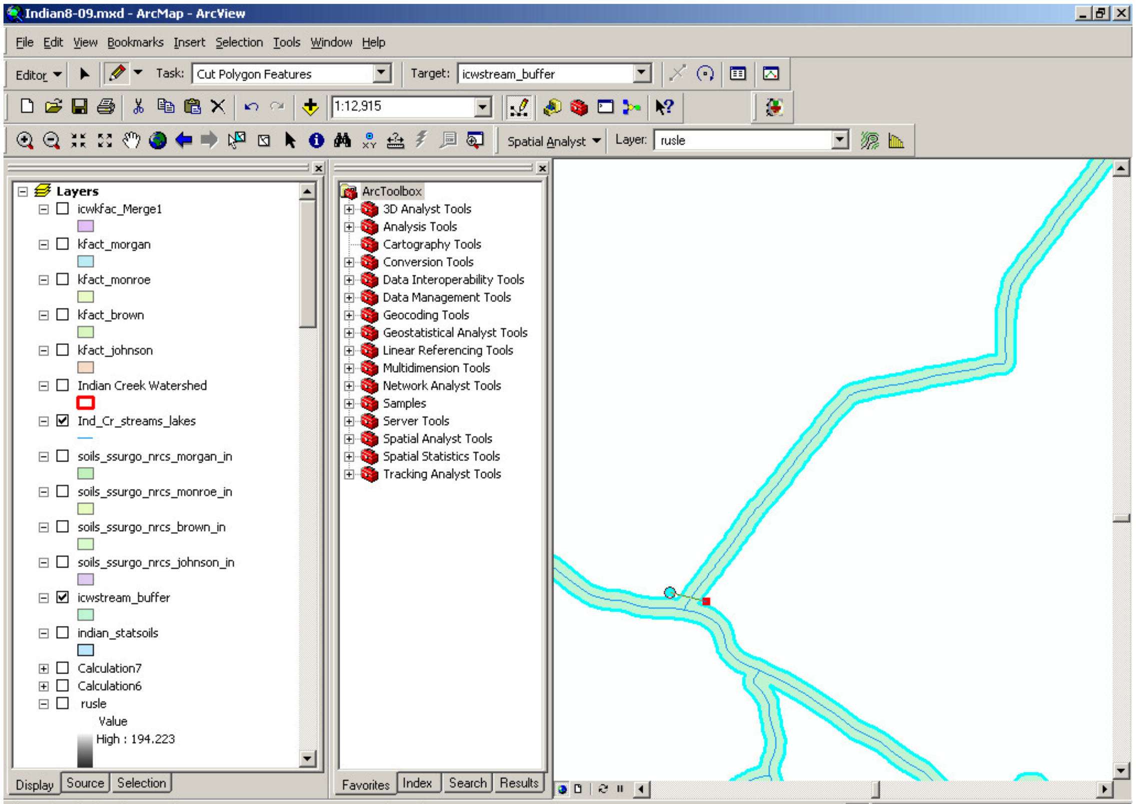


Figure 45. Select the stream so that it is highlighted.

To measure a length of stream reach, use the measure tool show in Figure 46. Begin measuring at the first cut till you reach 800 m (approximately 0.5 miles).

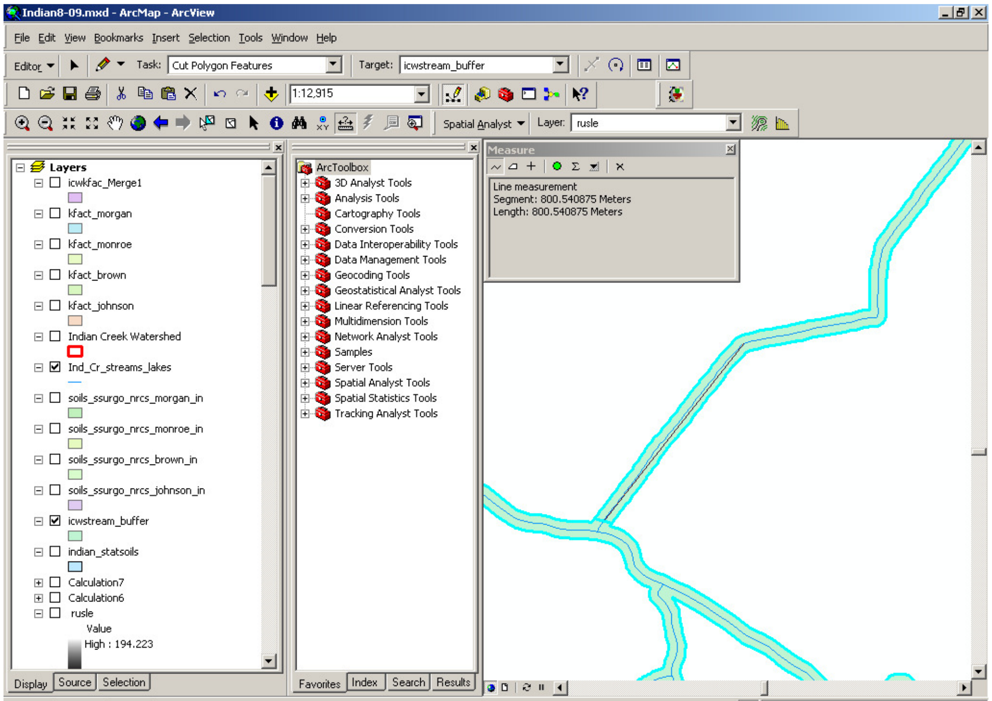


Figure 46.

Then cut the polygon at that 800 meter point (Figure 47).

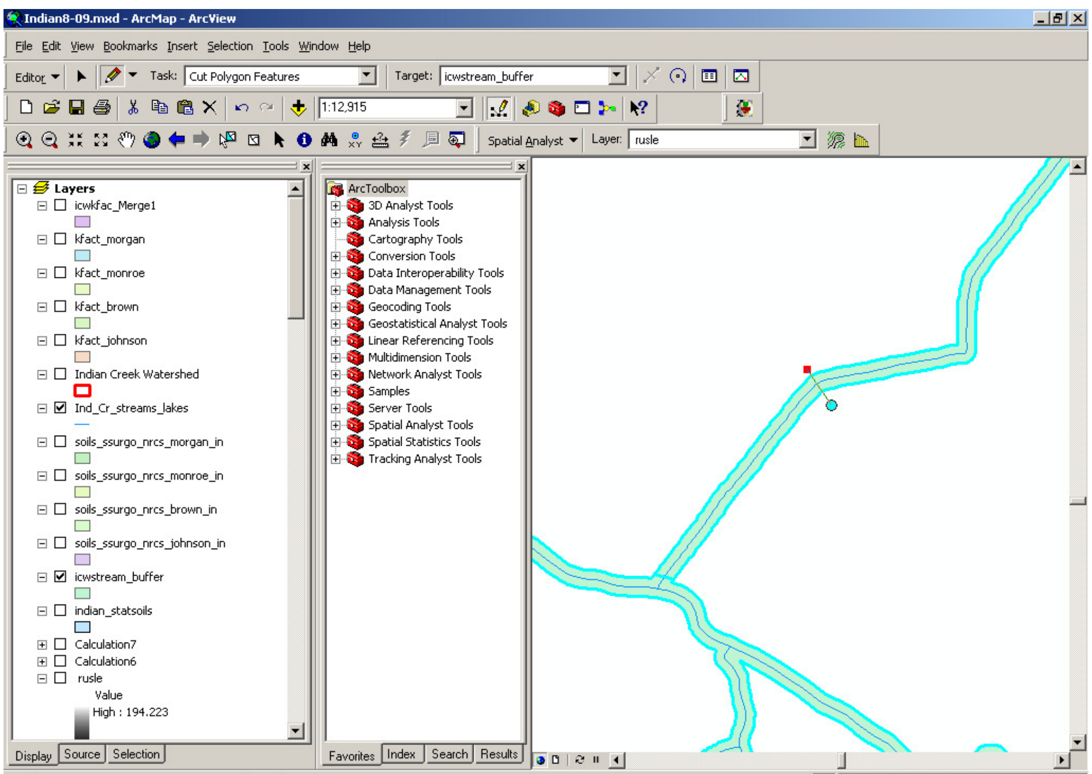


Figure 47.

Now select the stream reach and create a layer from it (Figure 48). Right click on the layer containing the stream segment, a menu box will appear, select "Selection" and from there select "Create Layer from Selected Features". Continue this stream reach creation and layer creation for each 800 meter segment of the stream network within the area being studied. This will be quite time consuming.

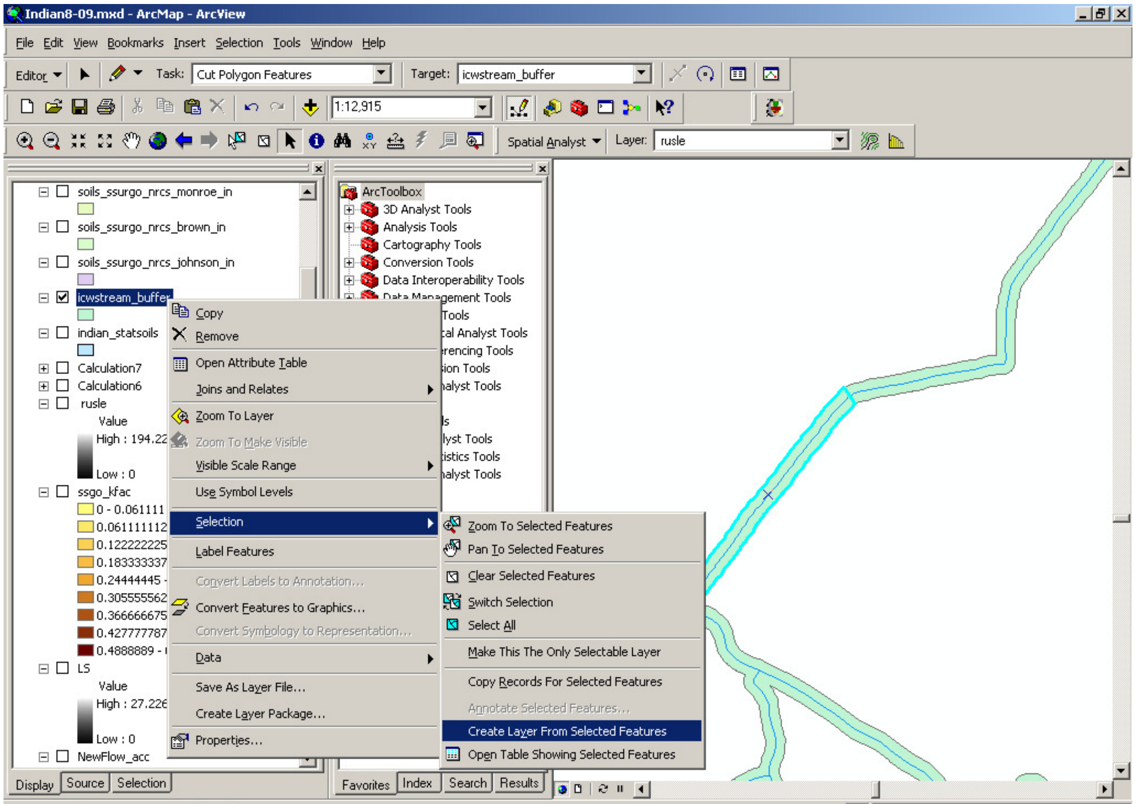


Figure 48.

Then use the reaches to extract the LULC layer and the RUSLE results layer. Calculate the % NPS contributing landuse and erosion rates for each stream reach using the same methods described and demonstrated in the previous steps (Figure 4). The width and length of your stream reaches can be modified to reflect needs and goals of your watershed.

Cutting stream reaches and extracting the land use and erosion rasters for the reaches is the most time consuming portion of this analysis. There is no automated way to do this and is very repetitive. Enjoy!!

4.3.3 Scoring

Data from each of the indicators shown above, from both the subwatershed and stream reach scales, will be given scores ranging from 1 to 3 based upon the placement of the data point within the dataset from each subwatershed. Divide the data from each subwatershed into thirds. If a data point falls in the lowest 1/3 of the data range, give it a score of 1. If it falls in the middle 1/3, give it a score of 2. If it falls within the highest 1/3, give it a score of 3. To calculate this, first calculate the range of the data (highest number minus lowest number) then divide~~d~~ by 3. Add that number to the minimum to give the data range for the lowest third. Any data that falls in the lowest third receives a score of 1 (Table 3).

For example:
Min= 0
Max=100
Range =100
Range/3=33.3

Scores
0-33.3 =**1** 33.4-66.6=**2** 66.7-100=**3**

All the scores from the four variables or indicators for subwatershed prioritization are then added and final scores ranged from 4 to 12 (Table 3). High numbers would be areas that have high pollution potential and need to be given restoration priority. Scoring for stream reaches also followed this same scoring schematic. The stream reaches only had two indicators, % NPS contributing LULC in the reach and erosion estimate within the reach, therefore the final scores ranged from 2 to 6. A score of two indicates a low potential for NPS pollution and thus a low need for riparian buffers. A high score of 5 or 6 indicates a high potential for NPS pollution and thus a high need for riparian buffers (Table 3).

Table 3. Prioritization scores for the seven subwatersheds within Indian Creek Watershed based upon the data from the four subwatershed indicators.

Indian Creek Watershed Final Subwatershed Scores

Subwatersheds	% Subwshd LULC	Score	% Rip LULC	Score	% Rip Land	Score	Erosion	Score	Final Score
1	33.9	1	9.17	1	9.31	2	6.2	2	6
2	71.48	3	27.46	3	8.21	2	9.6	3	11
3	51.32	2	25.01	3	9.02	2	7.43	2	9
4	36.95	1	17.86	2	11.39	3	7.21	2	8
5	31.56	1	27.7	3	8.6	2	5.1	1	7
6	24.14	1	20.41	2	8.97	2	6.15	2	7
7	59.85	3	21.72	3	6.52	1	4.4	1	8

5. Tool Modifications

Each and every watershed is very different. Additionally each watershed group is very individualized and all have varying needs and goals for their watersheds. There must be room in a tool of this nature for modifications to take into account those differences. Some indicators may not give information that is useful in determining riparian conditions. For instance, the percent riparian area may prove useless in a watershed whose streams highly altered, straightened and channelized. In this case, the percent of riparian area in each subwatershed would be virtually the same, making this indicator of no value for use in this tool. In this instance that indicator should be thrown out. Indicators can be added to this tool assuming that they deal directly with subwatershed, riparian and or stream condition. Any data available on the chemical, biological and or physical state of a stream is acceptable for subwatershed prioritization, provided that this information is available for every subwatershed within the larger watershed, if not available for every subwatershed then this data wouldn't be useful for this ranking system. Another beneficial indicator would be percent of impervious surface within the subwatershed. Research has shown that the amount of impervious surfaces, such as roof tops and parking lots, have a significant negative correlation to stream health. Areas with percentages higher than 10% impervious surfaces exhibit significant watershed problems (Center for Watershed Protection). Another modification could be to use a different loading model. RUSLE was used as the loading model because sediment is the # 1 polluter to both the nations and Indiana's surface waters. Also the staff that developed this tool was most comfortable with this model. However others may be more comfortable with a different loading model that has more capabilities and is more or less complex depending upon their experience in this area. For example, there is a method, developed by Purdue University's Department of Agricultural and Biological Engineering, to run the LTHIA model on a specified watershed with in Indiana via an online application (Purdue Research Foundation). (https://engineering.purdue.edu/~lthia/) A comparison of the substitution of LTHIA model for the RUSLE model showed only minor changes in the overall subwatershed rankings.

6. Creating, Using and Interpreting Output

Table 3 is simply created using a new sheet in the existing excel file and transferring final indicator values from the data in the files. The table for stream reach indicator values and scores is created in the same manner.

To create maps of the data take the shape file layer containing the just the subwatershed delineations and begin to add fields shown in the red oval in Figure 49 to the attribute table. Then enter the rankings for each indicator into each subwatershed, be sure to turn on the editor to do this.

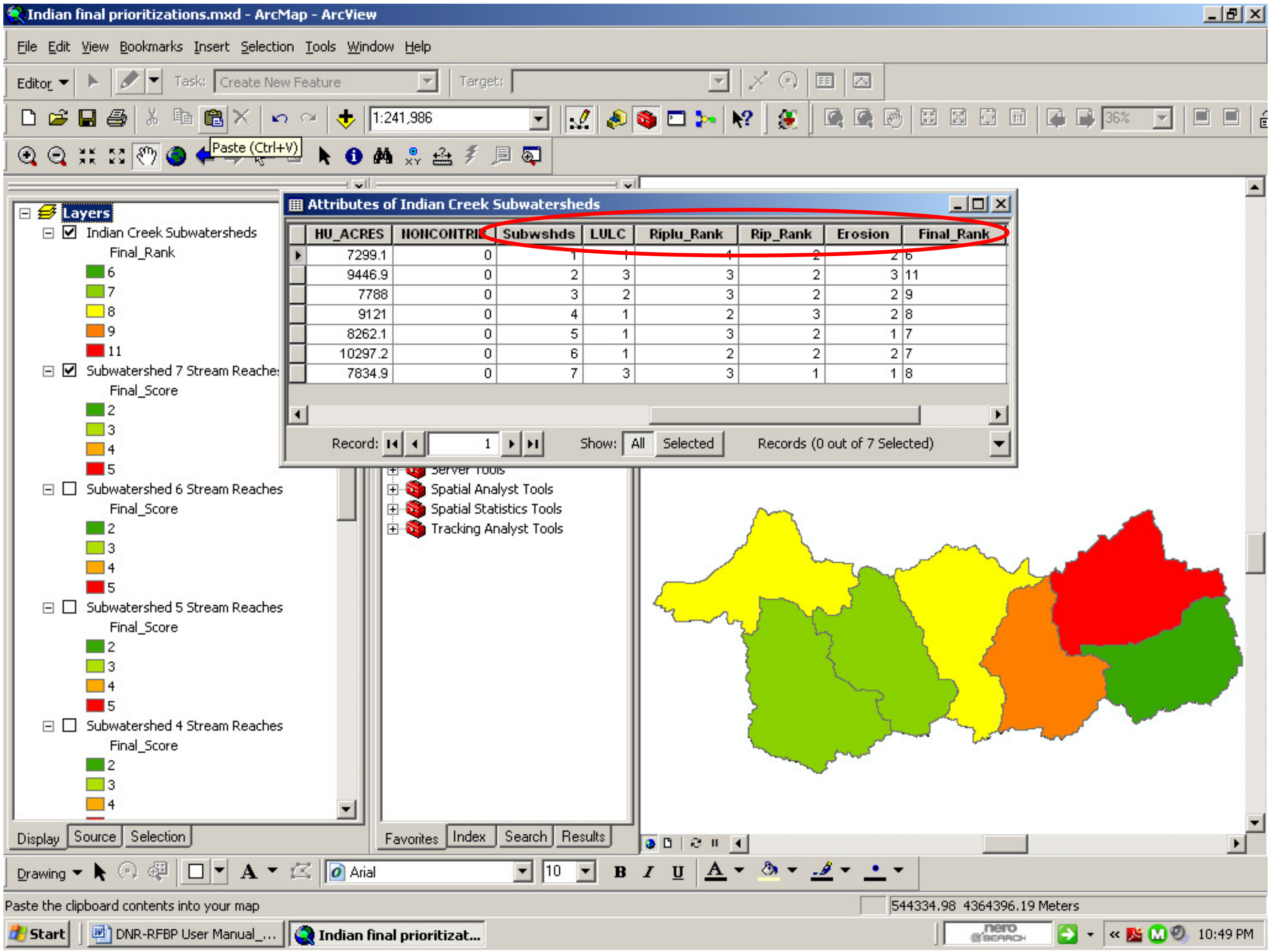


Figure 49.

The next step is creating the symbology for the layer (Figure 50). First double click the layer name and the "Layer Properties" dialog box will appear, click the "Symbology" tab. Under the "Fields" section click the drop down menu by "Value" select one of the indicator fields that was just created. Make sure you are on graduated colors and that the number of fields is equal to the number of ranking values in the field. Make sure the labels are correct, for example if there is no ranking of 10 the symbology will automatically label the ranking as 10-11. Double click the label and it can be changed to 11. Repeat this process for all four subwatershed indicator rankings as well as the final subwatershed ranking. This is done by copying the layer and repeating the above process.

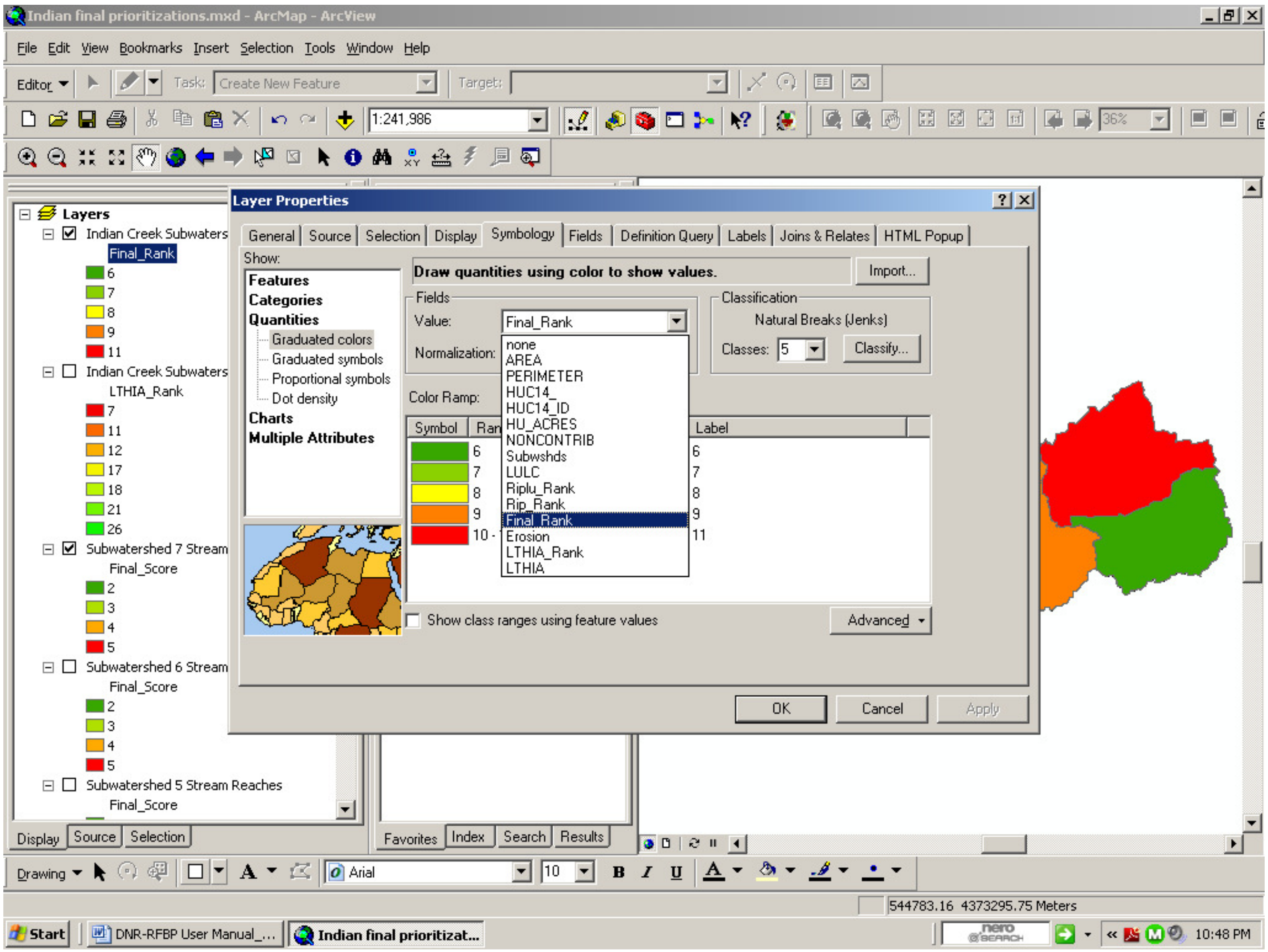


Figure 50.

To create the stream reach final maps the stream reaches first must all be merged (Figure 51). This is found under the "Data Management Tools" in "General" then click "Merge". There will be a drop down arrow under Input Data and you will begin adding the stream reaches starting with the first one and staying in order. Be sure to double check the order and completeness of the list before clicking ok, as the list will likely be quite long. When this is complete name the file appropriately. Next add the fields circled in red (Figure 52). Turn on editor and add the indicator values to the appropriate stream reaches, be sure to save edits and stop editing when finished. Copy the created layer and repeat the above process for both indicators and the final stream reach ranking.

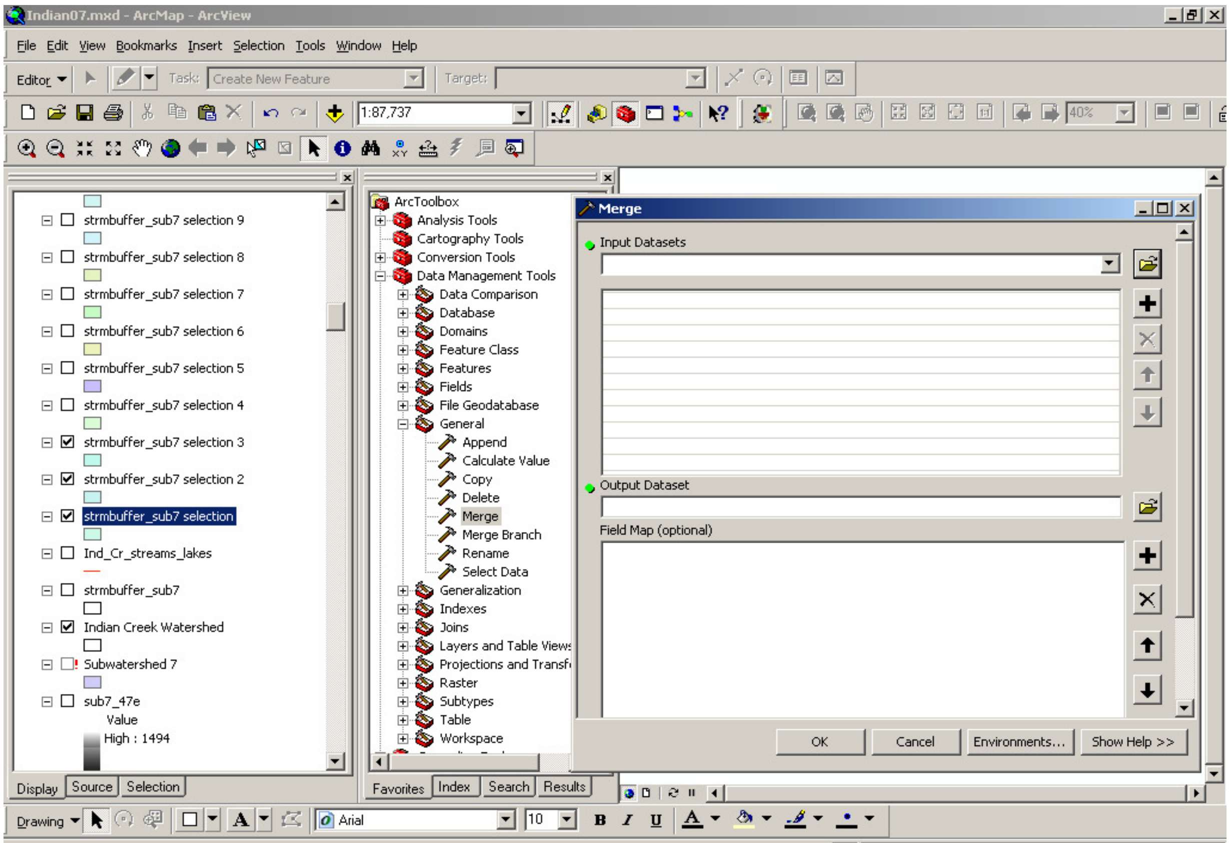


Figure 51.

Next add the fields circled in red (Figure 52). Turn on editor and add the indicator values to the appropriate stream reaches, be sure to save edits and stop editing when finished. Copy the created layer and repeat the above process for both indicators and the final stream reach ranking.

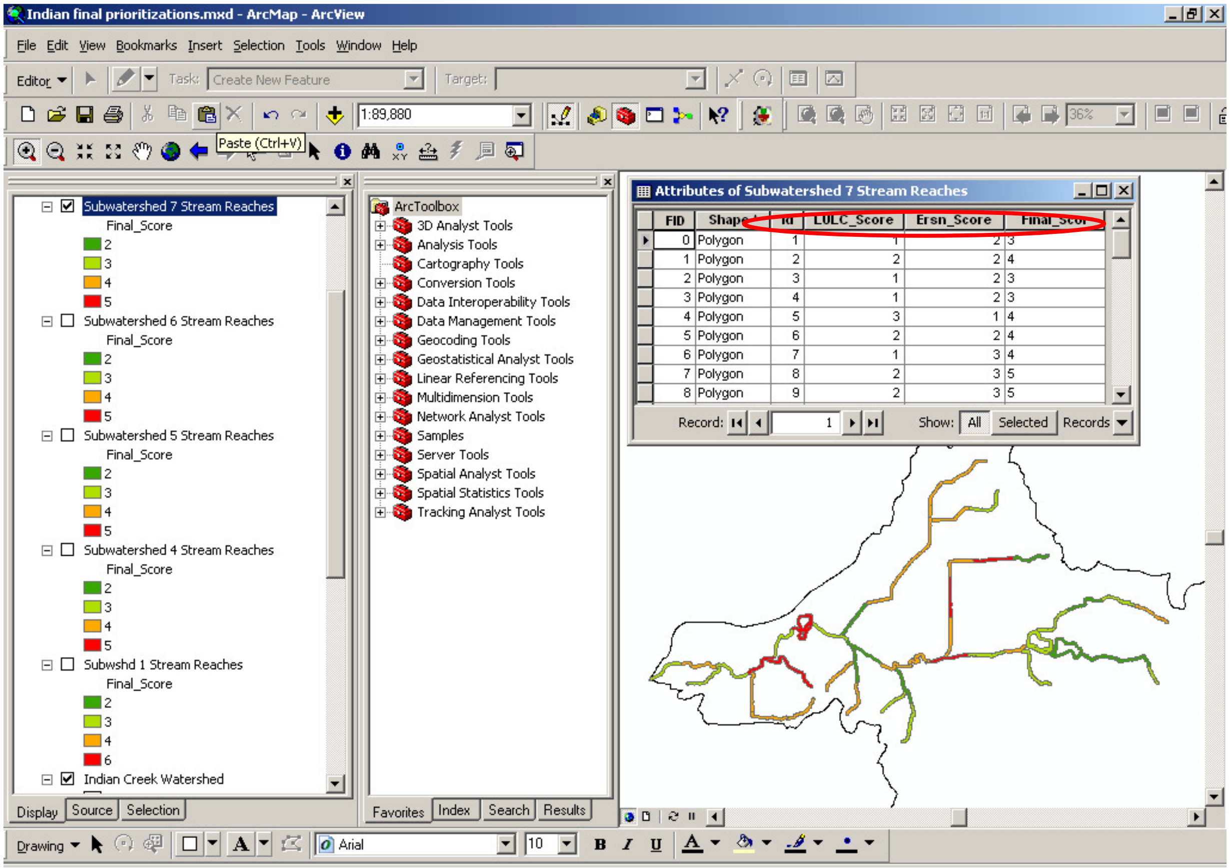


Figure 52.

Below are the outputs from the tool for the Indian Creek Watershed. Table 2 shows the indicator values for each of the 4 indicators for subwatershed prioritization and the corresponding scores. Figures 53 - 56 show the maps of the indicator scores for each subwatershed within Indian Creek Watershed. The final subwatershed prioritization for riparian forest buffer placement is shown in Figure 57. Figures 58 & 59 are the maps for the indicators for the stream reaches located within the highest ranked subwatershed (watershed with most NPS pollution potential, most in need of RFBs). Figure 60 is the final stream reach map for the selected subwatershed in Indian Creek Watershed. These model outputs are included so that the users will have an idea of the products that this tool can produce.

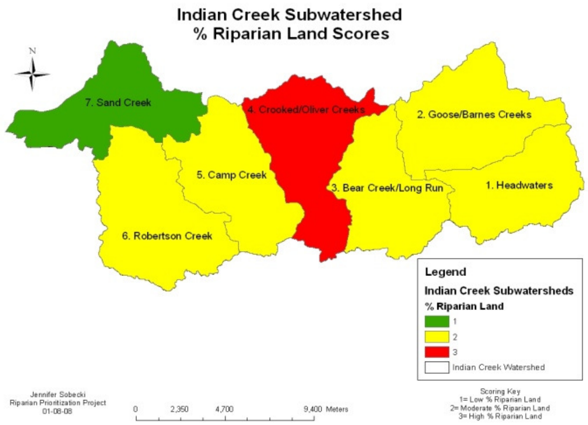


Figure 53.

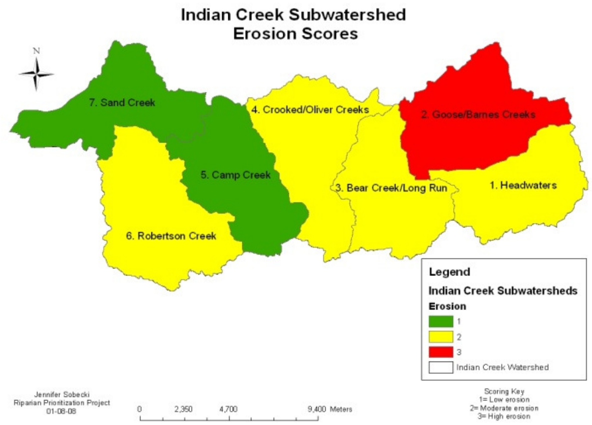


Figure 54.

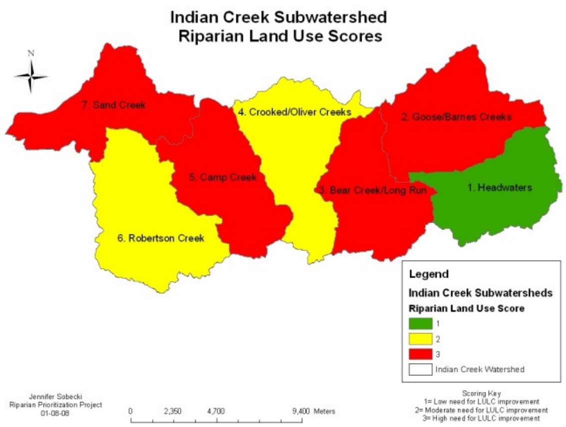


Figure 55.

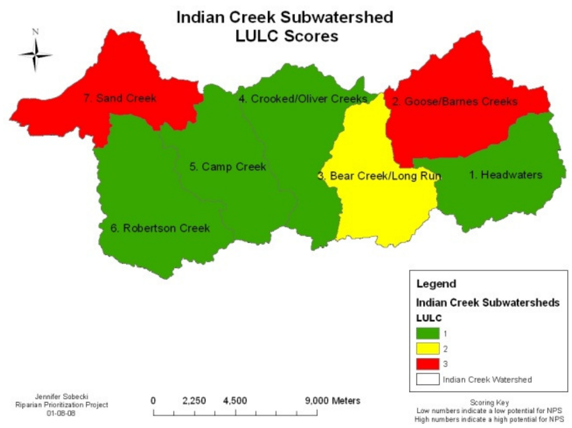


Figure 56.

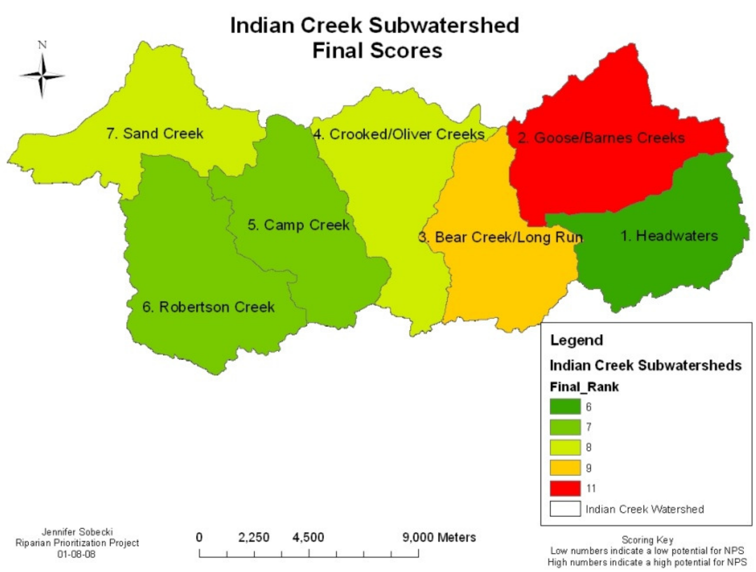


Figure 57.

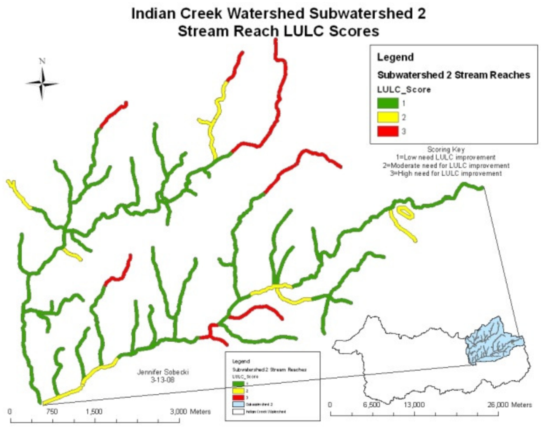


Figure 58.

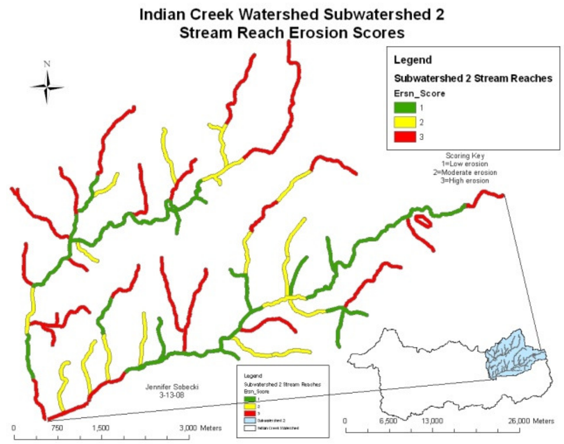


Figure 59.

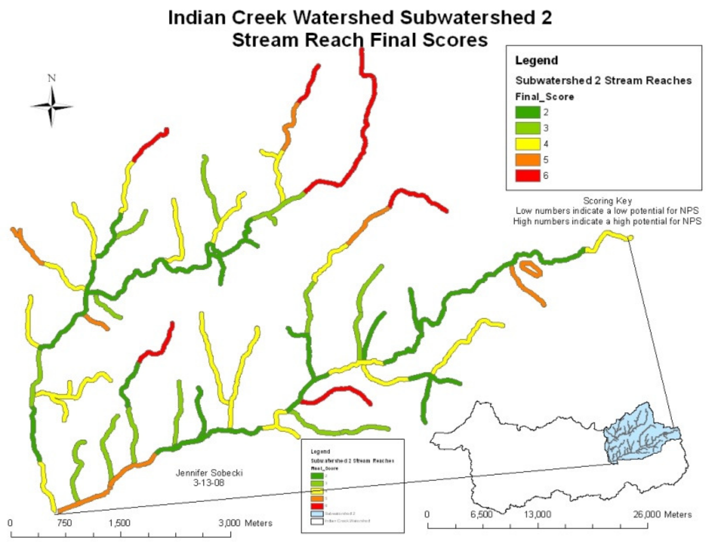


Figure 60.

As previously stated, this tool is intended to be used for watershed planning, specifically to determine areas that most need RFBs in order to effectively and efficiently reduce the delivery of NPS pollution to surface waters. This tool can help watershed groups to design and implement riparian restoration, enhancement and protection plans. The red and orange areas in the map indicate areas of high priority and thus, would generally be considered for areas to focus on restoration. Yellow areas are locations where enhancement of the existing buffer could improve the current riparian conditions. The green areas are locations where generally a good riparian buffer is in place, however protection plans need to be implemented as land use is continually changing and therefore areas in good condition need to be protected from encroachment.

Most watershed groups have some type of educational component written into the plans. These model outputs can be used to determine areas to focus educational efforts.

The outputs of this tool can also be used to tie to a cost-share ranking. This would give a higher priority for funding to areas that have the highest ranking for RFB placement.

7. Tool Limitations

There has been no ground truthing completed to validate the tool outcomes. This is the responsibility of the user. This tool is not intended to replace on-the-ground surveys, which are critically important in any kind of watershed assessment, but to be an accompaniment to them. The information that is derived from this tool is only as accurate as the data from which it originated; therefore the user must keep in mind the spatial and temporal data resolution and error inherent in all spatial data. This tool is intended to be a general assessment of riparian conditions using readily available GIS data that will determine areas for riparian restoration, enhancement and protection.

References

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Appendix A.

R-Values for Indiana Counties

Name	R mean
Adams	160.0
Allen	160.0
Bartholomew	180.0
Benton	180.0
Blackford	160.0
Boone	180.0
Brown	180.0
Carroll	180.0
Cass	180.0
Clark	180.0
Clay	200.0
Clinton	180.0
Crawford	200.0
Daviess	200.0
De Kalb	180.0
Dearborn	180.0
Decatur	140.0
Delaware	160.0
Dubois	200.0
Elkhart	160.0
Fayette	180.0
Floyd	180.0
Fountain	180.0
Franklin	180.0
Fulton	160.0
Gibson	220.0
Grant	160.0
Greene	200.0
Hamilton	180.0
Hancock	180.0
Harrison	180.0
Hendricks	180.0
Henry	160.0
Howard	180.0
Huntington	160.0
Jackson	180.0
Jasper	160.0
Jay	160.0
Jefferson	180.0
Jennings	180.0
Johnson	180.0
Knox	200.0
Kosciusko	159.7
La Porte	140.0
Lagrange	160.0
Lake	160.0
Lawrence	200.0

Madison	160.0
Marion	180.0
Marshall	160.0
Martin	200.0
Miami	160.0
Monroe	200.0
Montgomery	180.0
Morgan	180.0
Newton	160.3
Noble	160.0
Ohio	180.0
Orange	200.0
Owen	200.0
Parke	180.0
Perry	200.0
Pike	200.0
Porter	160.0
Posey	220.0
Pulaski	160.0
Putnam	180.0
Randolph	160.0
Ripley	180.0
Rush	180.0
Scott	160.0
Shelby	180.0
Spencer	180.0
St. Joseph	200.0
Starke	160.0
Steuben	140.0
Sullivan	200.0
Switzerland	180.0
Tippecanoe	180.0
Tipton	180.0
Union	160.0
Vanderburgh	219.5
Vermillion	180.0
Vigo	199.8
Wabash	160.0
Warren	180.0
Warrick	200.0
Washington	180.0
Wayne	160.0
Wells	160.0
White	180.0
Whitley	160.0